Draft

Bacteria, Benthic, and Temperature Total Maximum Daily Loads in the Little River Watershed of Floyd and Montgomery Counties, Virginia

(A Nested TMDL Approach)

Photo

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Table C. 5 Monthly, directly deposited fecal coliform loads in each reach of the Little River (Reaches 1,2,3,4,5,6,7,8,9,10,11,12,13,14,16,17,18,19,20,21,25,26, (cont.) C-6

Table C. 6 Existing annual loads from land-based sources for the Little River (Sub-watersheds 1,2,3,4,5,6,7,8,9,10,11,12,13,14,16,17,18,19,20,21,25,26,27): C-7

Table C. 7 Existing annual loads from direct-deposition sources for the Little River (Reaches 1,2,3,4,5,6,7,8,9,10,11,12,13,14,16,17,18,19,20,21,25,26,27): C-8

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ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

Background and Applicable Standards

There are nine different impaired streams in this study area, Little River, Meadow Run, Pine Creek, West Fork Dodd Creek, Dodd Creek, Meadow Creek, Brush Creek, Laurel Creek and Big Indian Creek. There are twenty-six (26) separate impaired segments.

Fifteen (15) segments have bacterial impairments, eight (8) have trout waters temperature impairments and three (3) have benthic macroinvertebrate impairments. Table ES.1 shows the details of these impairments.

For the General Standard violations (benthic macroinvertebrate), a process called a stressor analysis is conducted to determine the likely cause of the impairment. The results of this process for the Little River and Meadow Run benthic impairments determined that sediment was the most probable stressor.

In Virginia, once a water body violates a given standard, a Total Maximum Daily Load (TMDL) must be developed. The TMDL is a pollution budget that determines the amount of pollutant the water body can receive in a given period of time and still meet the intended standard.

Table ES.1 Impairments within the Little River watershed included in this study.

Stream Name Assessment Unit ID	**Impairment Contracted**	**Initial Listing Year**	**2008 River Miles**	**2008 Listing Violation[1] Rates**	**Impairment Location Description**
Little River VAW-N19R_LRV01A00	Bacteria	2006	8.60	27.3	Confluence with Oldfield Creek downstream to the confluence with West Fork Little River.
Little River VAW-N19R_LRV01A0	Temperature	2008		16.7[1]	
Little River VAW-N19R_LRV02A00	Bacteria	2006	10.91	33.3	Confluence with Meadow Creek downstream to the confluence with Oldfield Creek.
Little River VAW-N19R_LRV02A00	Temperature	2002		16.7[1]	
Little River VAW-N19R_LRV03A00	Bacteria	2006	14.04	36.4 33.3	Confluence with Payne Creek downstream to the confluence with Meadow Creek.
Little River VAW-N19R_LRV03A00	Temperature	2008		16.7[1]	
Little River VAW-N21R_LRV06A04	Bacteria	2004	13.33	36.4[2]	End of Rt. 706 downstream to the confluence with Sidney Creek.
Little River VAW-N21R_LRV06A04	Benthic	2008		NA	
Little River VAW-N21R_LRV07A00	Bacteria	2006	3.66	27.3	West Fork Little River confluence downstream to the WQS natural trout waters designation.
Little River VAW-N21R_LRV07A00	Benthic	2008		NA	
Little River VAW-N21R_LRV01A00	Bacteria	2004	0.48	28.6[2]	Little River Reservoir dam downstream to the New River confluence.
Little River VAW-N21R_LRV03A00	Bacteria	2002	0.68	28.6[2]	PWS designated section for Radford downstream to the backwaters of the Little River Reservoir.

[1] Temperature impairment based on the natural trout maximum temperature WQS of 20^0C. Bacteria impairments are based on the instantaneous *E. coli* WQS of 235 cfu/100mL for samples collected during the most recent data period assessment unless otherwise noted.
[2] Based on the instantaneous fecal coliform WQS of 400 cfu/100mL

Table ES.1 Impairments within the Little River watershed (cont.).

Stream Name Impairment Id	**Impairment Contracted**	**Initial Listing Year**	**2008 River Miles**	**2008 Listing Violations/ Total Samples**	**Impairment Location Description**
Little River VAW-N21R_LRV04A00	Bacteria	2002	0.67	4/14[2]	Confluence with Meadow Creek downstream to the PWS section.
Little River VAW-N21R_LRV05A00	Bacteria	2006	12.22	2/11[2]	Big Indian Creek confluence downstream to the Meadow Creek confluence.
Little River VAW-N21R_LRV06A00	Bacteria	2006	8.01	2/10[2]	WQS natural trout waters section downstream to the confluence with Big Indian Creek.
Little River (Reservoir) VAW-N21L_LRV01A02	Bacteria	2008	60.44[1]	2/7[2]	From the reservoir backwaters to the dam.
Meadow Run VAW-N19R_MDR01A04	Bacteria	2006	3.70	4/12	From the headwaters downstream to the confluence with Little River.
Meadow Run VAW-N19R_MDR01A04	Benthic	2008		NA	
Pine Creek VAW-N19R_PNC01A06	Bacteria	2006	3.68	3/11	From the impounding structure of a pond downstream to the Little River confluence.
Pine Creek VAW-N19R_PNC01A06	Temperature	2008		2/12[3]	
West Fork Dodd Creek VAW-N20R_DDW01A02	Temperature	2002	1.17	2/2[3]	From an unnamed tributary downstream the confluence with Dodd Creek.
Dodd Creek VAW-N20R_DDD01A00	Temperature	2008	3.78	2/9[4] 2/9[4]	Floyd County PSA outfall downstream to the West Fork Little River confluence.
Dodd Creek VAW-N20R_DDD02A00	Temperature	2008	2.50	1/2[4] 1/1[4]	West Fork Dodd Creek confluence downstream to the Floyd County PSA outfall.

Bacteria impairments are based on the instantaneous *E. coli* WQS of 235 cfu/100mL for samples collected during the most recent data period assessment unless otherwise noted

[1] acres

[2] Based on the instantaneous fecal coliform WQS of 400 cfu/100mL .

[3] Based on the natural trout maximum temperature WQS of 20^0C

[4] Based on the stockable trout maximum temperature WQS of 21^0C

Table ES.1 Impairments within the Little River watershed (cont.).

Stream Name Impairment Id	**Impairment Contracted**	**Initial Listing Year**	**2008 River Miles**	**2008 Listing Violations[1]/ Total Samples**	**Impairment Location Description**
Meadow Creek VAW-N21R_MDW01A00	Bacteria	2002	4.49	7/12[1]	From the Mill Creek confluence downstream to the Little River confluence.
Brush Creek VAW-N21R_BSH01A04	Bacteria	2004	5.76	5/10[1]	From the Rt. 617 bridge downstream to the Little River confluence.
Laurel Creek VAW-N21R_LLL01A04	Bacteria	2004	3.26	5/10[1]	From its headwaters downstream to the Little River confluence
Big Indian Creek VAW-N21R_BIC01A02	Temperature	2004	7.56	2/11[2]	0.5 miles upstream from the West Fork Big Indian Creek confluence downstream to the confluence with Little River.

[1] Based on the instantaneous fecal coliform standard of 400 cfu/100mL or the instantaneous during the 2004 assessment cycle.
[2] Based on sampling during the 2004 assessment cycle, the results are based on the stockable trout maximum temperature WQS of 21^0C.

TMDL Endpoint and Water Quality Assessment

Fecal bacteria TMDLs in the Commonwealth of Virginia are developed using the *E. coli* standard. For this TMDL development, the in-stream *E. coli* target was a geometric mean not exceeding 126-cfu/100 mL. A translator developed by VADEQ was used to convert fecal coliform values to *E. coli* values.

The General Standard states that waters should be free of substances that are harmful to aquatic life. The stressor determined to be impacting the aquatic life in the Little River and Meadow Run is sediment. The sediment endpoints were calculated from a reference watershed.

The temperature endpoints for the designated trout waters are the maximum values specified in the water quality standards. For natural trout waters the maximum temperature standard is 20^0 centigrade and for stockable trout waters the standard is 21^0 centigrade.

Source Assessment

Sources of bacteria and sediment were identified and quantified in the Little River watershed. Sources included point sources as well as non-point sources. The quantification of sources is important to determine the baseline of current conditions that is causing the impairment. Sources of bacteria included human, livestock, wildlife, pets, as well as permitted point sources. Sediment sources coming from various activities such as farming and development, as well as, permitted point sources and streambank erosion were quantified. Parameters influencing the impaired temperature segments were obtained from geographic information systems, channel geometry, flow records, and meteorological data.

Modeling Procedures

Computer modeling is used to relate the sources on the ground to the water quality in the streams and rivers. This is important since not every colony of bacteria or every amount of sediment in the Little River watershed ends up in the streams and rivers. The computer models help quantify the portion of bacteria and sediment within the Little River watershed that ends up in the stream.

The computer modeling process consists of several steps. First, the characteristics of the drainage area including land use, slopes, stream network, soil properties, are entered into the model. The parameters influencing bacteria, sediment, and temperature are also entered into the corresponding model. A process known as calibration is then conducted by comparing model simulations with monitored field data. Model parameters are adjusted during calibration to minimize the error between simulated and monitored values. This process is conducted for hydrology (flow) as well as water quality. Once the model is calibrated, it is then used to determine the existing water quality conditions in the study area and may be used to determine the reductions necessary to meet the water quality standard or endpoint.

Hydrology (for Bacteria Modeling)

The US Geological Survey (USGS) Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to model hydrology and fecal coliform. For purposes of modeling the Little River watershed, inputs to streamflow and in-stream fecal bacteria, the drainage area was divided into nine (9) subwatersheds.

Daily precipitation data was available within the watershed at the Floyd 2 NE NCDC Coop station # 443071. Missing values were filled using daily precipitation from the Willis NCDC Coop station # 449169 and Christiansburg NCDC Coop station 441692. The final filled daily precipitation was disaggregated using the hourly station data.

The model was calibrated for hydrologic accuracy using daily flow data for the period October 1993 through September 1996. The modeled output from subwatershed 3 was compared against the Little River USGS Gaging Station #03170000 data. The modeled output was validated for the period of October 2005 to September 2008.

Fecal Coliform

Wildlife populations, the rate of failure of septic systems, domestic pet populations, and numbers of livestock are examples of land-based nonpoint sources used to calculate fecal coliform loads. Also represented in the model were direct sources of uncontrolled discharges, direct deposition by wildlife, direct deposition by livestock, and direct inputs from sewer overflows. Contributions from all of these sources were updated to current conditions to establish existing conditions for the watershed.

The fecal coliform calibration was conducted using monitored data collected at VADEQ monitoring station 9-LRV000.34 for the period of October 2000 to September 2003. Water quality validation was conducted using data collected from the same VADEQ monitoring station for the period of October 1997 to September 2000.

Sediment

The model used in this study was the *Visual Basic™* version of the Generalized Watershed Loading Functions (GWLF) model with modifications for use with ArcView (Evans et al., 2001). The target TMDL load for the Little River is the average annual load in metric tons per year (t/yr) from the area-adjusted Big Reed Island Creek watershed under existing conditions. The Big Reed Island Creek watershed was used as a reference watershed since it is meeting the General Standard. To reach the TMDL target goal (8,166 t/yr), different scenarios were run with GWLF.

Temperature

Temperature was modeled within the impaired segments using the USGS Stream Segment Temperature Model (SSTEMP). The model utilizes geometry, meteorology, shade, and flow conditions within the stream segment to predict maximum temperature. A total of five segments were modeled not to exceed the 20 ^{o}C maximum temperature for the natural trout streams. Three other segments were modeled not to exceed the 21 ^{o}C for stockable trout streams.

Load Allocation Scenarios

The next step in the TMDL processes was to reduce the various source loads to levels that would result in attainment of the water quality standards or endpoints. Scenarios were evaluated to predict the effects of different combinations of source reductions on final in-stream water quality. The final TMDL information is shown in Table ES.2.

The final bacterial TMDLs for the Little River watershed include 100% reductions in straight pipes and sewer overflows.

Table ES.2 Average annual in-stream cumulative pollutant loads modeled after allocation in the Little River impairments.

Pollutant	Units	Impairment	WLA[1]	LA	MOS	TMDL
E. coli	cfu/yr	**Little River**	1.13E+13	1.12E+15	*Implicit*	1.13E+15
Sediment	t/yr	**Little River**	116.49	8,050.34	907.46	9,073.87
Temperature	Joules /m^2/s	**Little River VAW-N19R_LRV01A00**	1.66	164.55	*Implicit*	166.21
Temperature	Joules /m^2/s	**Little River VAW-N19R_LRV02A00**	1.44	142.58	*Implicit*	144.02
Temperature	Joules /m^2/s	**Little River VAW-N19R_LRV03A00**	1.03	101.69	*Implicit*	102.72
Temperature	Joules /m^2/s	**Pine Creek VAW-N19R_PNC01A06**	1.35	133.5	*Implicit*	134.85
Temperature	Joules /m^2/s	**W.F. Dodd Creek VAW-N20R_DDW01A02**	0.99	98.09	*Implicit*	99.08
Temperature	Joules /m^2/s	**Dodd Creek VAW-N20R_DDD02A00**	1.3	128.67	*Implicit*	129.97
Temperature	Joules /m^2/s	**Dodd Creek VAW-N20R_DDD01A00**	0.82	80.99	*Implicit*	81.81
Temperature	Joules /m^2/s	**Big Indian Creek VAW-N21R_BIC01A02**	1.2	119.01	*Implicit*	120.21

[1] WLA by permit can be found in the corresponding allocation chapters.

Implementation

The goal of the TMDL program is to establish a path that will lead to attainment of water quality standards. The first step in this process is to develop TMDLs that will result in meeting water quality standards. This report represents the first phase of that effort for the impairments in the Little River watershed. The next step will be more monitoring to better establish the sources of TSS. Development of TMDL implementation plans (IP) will follow the phased TMDL process. The final step is to implement the TMDL IPs and to monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL IP is developed, VADEQ will take the plan to the State Water Control Board (SWCB) for approval for implementing the pollutant allocations and reductions contained in the TMDL. Also, VADEQ will request SWCB authorization to incorporate the TMDL implementation plan into the appropriate waterbody. With successful completion of implementation plans, Virginia begins the process of restoring impaired waters and enhancing the value of this important resource.

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use. In order for a stream to be assigned, a new designated use, or a subcategory of a use, the current designated use must be removed. The state must also demonstrate that attaining the designated use is not feasible. Information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted by the SWCB as amendments to the water quality standards regulations. During the regulatory process, watershed stakeholders and other interested citizens as well as EPA will be able to provide comment during this process.

Public Participation

During development of the TMDL for the impairments in the Little River study area, public involvement was encouraged through a first public meeting (9/28/2010), and a final public meeting (2/?/2011). An introduction of the agencies involved, an overview of the TMDL process, details of the pollutant sources, and the specific approach to developing the Little River watershed TMDLs were presented at the first of the public meeting. Public understanding of and involvement in, the TMDL process was encouraged. Input from this meeting was utilized in the development of the TMDL and improved confidence in the allocation scenarios. The model simulations and the TMDL load allocations were presented during the final public meeting. There was a 30-day public comment period after the final public meeting. Written comments were addressed in the final document.

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1. INTRODUCTION

1.1 Regulations Background

The Clean Water Act (CWA) that became law in 1972 requires that all U.S. streams, rivers, and lakes meet certain water quality standards. The CWA also requires that states conduct monitoring to identify waters that are polluted or do not otherwise meet standards. Through this required program, the Commonwealth of Virginia has found that many stream segments do not meet state water quality standards for protection of the six beneficial uses: recreation/swimming, aquatic life, wildlife, fish consumption, shellfish consumption, and public water supply (drinking).

When streams fail to meet standards, the stream is “listed” in the current Section 303(d) report as requiring a Total Maximum Daily Load (TMDL). Section 303(d) of the CWA and the U.S. Environmental Protection Agency’s (EPA) Water Quality Management and Planning Regulation (40 CFR Part 130) both require that states develop a Total Maximum Daily Load (TMDL) for each pollutant. A TMDL is a "pollution budget" for a stream; that is, it sets limits on the amount of pollution that a stream can tolerate and still maintain water quality standards. In order to develop a TMDL, background concentrations, point source loadings, and nonpoint source loadings are considered. A TMDL accounts for seasonal variations and must include a margin of safety (MOS).

Once a TMDL is developed and approved by EPA, measures must be taken to reduce pollution levels in the stream. Virginia’s 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) states in section 62.1-44.19:7 that the *“Board shall develop and implement a plan to achieve fully supporting status for impaired waters”*. The TMDL Implementation Plan (IP) describes control measures, which can include the use of better treatment technology and the installation of best management practices (BMPs), which should be implemented in a staged process. Through the TMDL process, states establish water-quality based controls to reduce pollution and meet water quality standards.

1.2 *Little River Watershed Characteristics*

The majority of the Little River watershed (USGS Hydrologic Unit Code 05050001) is located in Floyd County, Virginia with smaller portions in Pulaski and Montgomery Counties in Virginia. The Little River flows west-northwest from the headwaters near Copper Hill in northeastern Floyd County downstream to its confluence with the New River at the Pulaski/Montgomery county line south of Radford, Virginia. This watershed is a part of the New/Kanawaha River basin, which drains via the Mississippi River to the Gulf of Mexico. The location of the watershed is shown in Figure 1.1.

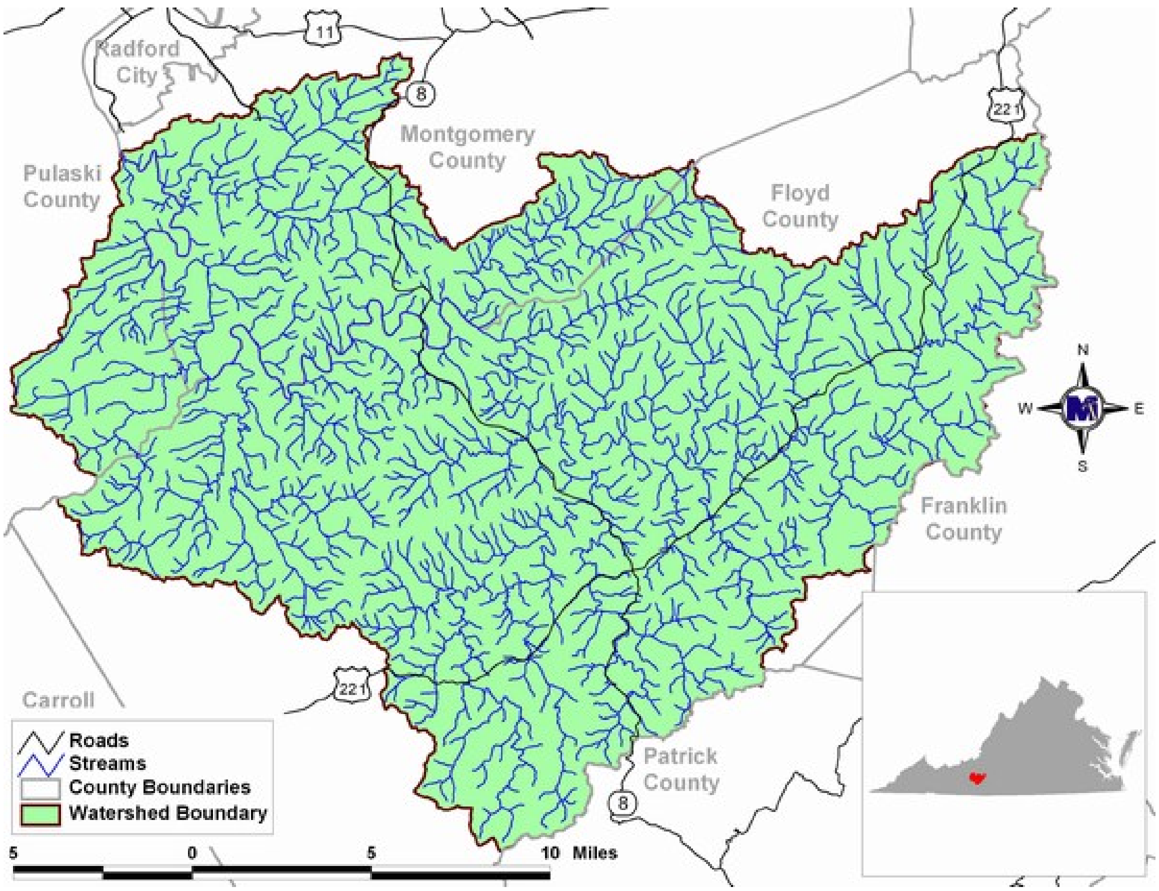

Figure 1.1 Location of the Little River watershed.

The Little River watershed lies within two level III ecorgeions. The Blue Ridge Mountains (66) level III ecoregion is a narrow strip of mountainous ridges that are forested and well dissected. Crestal elevations range from about 1,000 feet to over 5,700 feet (305 to 1,737 m) on Mt. Rogers and tend to rise southward. Local relief is high and both the side slopes and the channel gradients are steep. Streams are cool and clear and have many riffle sections; they support a different, less diverse fish assemblage than the streams of the valleys below, which are warmer, lower in gradient, and more turbid.

The Blue Ridge Mountains are underlain by resistant and deformed metavolcanic, igneous, sedimentary, and metasedimentary rock. Inceptisols, Ultisols, and Alfisols have developed on the Cambrian, Paleozoic, and Precambrian rock.

The Blue Ridge Mountains can be divided into northern and southern parts at the Roanoke River. North of the river, just three different rock types form the crest and the effects of differential erosion partially determine their local altitude. South of the Roanoke River, the Blue Ridge Mountains become higher and lithologically complex.

Climate varies significantly. Generally, both growing season and precipitation increase southward. The frost-free period varies from less than 150 days to more than 175 days. Locally, however, relief and topographic position have significant effects on the microclimate.

The natural vegetation varies from north to south. North of a transitional area near the Roanoke River, it was predominantly Appalachian Oak Forest (dominated by white and red oaks). South of the transitional area, grows a mix of Appalachian Oak Forest, Oak-Hickory-Pine Forest (dominants: hickory, longleaf pine, shortleaf pine, loblolly pine, white oak and post oak), and, in higher areas, Northern Hardwoods (dominants: sugar maple, yellow birch, beech, and hemlock). On the foothills, a mix of loblolly and shortleaf pines occurred and were mixed with Appalachian Oak Forest.

The Interior Plateau (66c) is a high, hilly plateau punctuated by scattered isolated knobs (monadnocks). It is more than 1,000 feet (304 m) higher than the nearby Piedmont; crestal elevations are approximately 2,600 to 4,500 feet (792 to 1,372 m). Local relief is often under 200 feet (61 m).

The Interior Plateau is underlain by Precambrian metamorphic rock, including quartzite, graywacke, and conglomerate of the Lynchburg Formation. Gneiss and schist also outcrop. Inceptisols, Alfisols, and Ultisols occur and Chester, Hayesville, Glenelg, Manor, and Myersville soils are common. Stoniness and limited depth to bedrock are characteristics of these soils.

The natural vegetation was Appalachian Oak Forest (dominated by white and red oaks) and Oak-Hickory-Pine Forest (dominants: hickory, longleaf pine, shortleaf pine, loblolly pine, white oak and post oak). Today, the Interior Plateau has woodlots interspersed with pastures. Livestock farms are common and some apple orchards also occur. Woodland remains on steeper slopes.

The Southern Sedimentary Ridges (66e) extends from the Roanoke River into Tennessee. It is composed of high, steeply sloping ridges and deep, narrow valleys. Crestal elevations range from about 2,600 to 4,425 feet (792-1,349 m) and are often higher than those of the Northern Sedimentary and Metasedimentary Ridges ecoregion (66b). Local relief ranges from about 500 to 1,150 feet (152-351 m).

Cambrian sedimentary and metasedimentary rocks, including sandstone and quartzite of the Chilowee Group, underlie Ecoregion 66e. Ridge crests are underlain by resistant sandstone and quartzite, while side slopes are made up of phyllite, shale, siltstone, and sandstone. Typically, Inceptisols (Dystrochrepts) developed from the bedrock. The Berks, Weikert, Dekalb, and Wallen soils are common.

The natural vegetation was Appalachian Oak Forest (dominants: white and red oaks) or, at higher elevations, Northern Hardwoods (dominants: sugar maple, yellow birch, beech, and hemlock) (Kuchler, 1964). Today, the Southern Sedimentary Ridges ecoregion remains extensively forested.

The Ridge and Valley (67) level III ecoregion extends from Wayne County, Pennsylvania, through Virginia along a southwesterly axis. It is characterized by alternating forested ridges and agricultural valleys that are elongated and folded and faulted. Elevations range from about 500 to 4,300 feet (152 to 1,311 m). Local relief varies widely from approximately 50 to 1,500 feet (15-457 m). The Ridge and Valley ecoregion narrows toward the south and is generally bordered by the higher Blue Ridge Mountains and the higher and less deformed Allegheny and Cumberland plateaus.

Underlying the Ridge and Valley ecoregion are largely Paleozoic sedimentary rocks that have been folded and faulted. Sandstone, shale, limestone, and dolomite are the predominant rock types. Lithological characteristics often determine surface morphology. Many ridges are formed on well-cemented, relatively resistant material such as sandstone or conglomerate; they are often rather parallel and alternate with valleys but, in central Pennsylvania, they zigzag because resistant strata were compressed into plunging folds during orogeny and later eroded. Valleys tend to be created on weaker strata, including limestone and shale. Inceptisols and Ultisols are common and were developed on noncarbonate rock. Alfisols and Ultisols are found in the limestone valleys.

The valleys vary in microtopography and agricultural potential. Valleys derived from limestone and dolomite are smoother in form and have a lower drainage density than those developed in shale. Shale valleys often display a distinctive rolling topography. Soils derived from limestone are fertile and well suited to agriculture, while those derived from shale have a much lower agricultural potential unless they are calcareous. Poultry operations are locally common and economically important.

Many of the streams networks are trellised; topography dictates that the swift, actively down-cutting streams which run off steep ridges must join the gentle valleys perpendicularly. Other larger rivers such as the Susquehanna River cross structure, cutting deep gorges through ridges in the process. High-gradient streams are common in watergaps and on ridge slopes; elsewhere, gentler gradient, warmer, more meandering streams are common. Partially as a result, the latitudinally extensive Ridge and Valley ecoregion has good aquatic habitat diversity.

The natural vegetation varied from north to south. From northeastern Pennsylvania to near its border with Maryland, the Ridge and Valley ecoregion was dominated by Appalachian Oak Forest. Southward, Oak-Hickory-Pine Forest (dominants: hickory, longleaf pine, shortleaf pine, loblolly pine, white oak and post oak) was common to about the James River, whereupon the Appalachian Oak Forest returned. Hemlock (Tsuga canadensis), along with a mixture of white pine (Pinus strobus), beech (Fagus grandifolia), and other hardwoods also occurred locally.

Climate varies significantly in the Ridge and Valley ecoregion. Generally, both growing season and precipitation increase southward. The frost-free period varies from less than 120 days to more than 180 days, however, relief and topographic position have significant effects on the microclimate. The Ridge and Valley ecoregion is significantly lower than the Central Appalachians ecoregion. As a result, it has less severe winters, considerably warmer summer temperatures, and lower annual precipitation due to a rain shadow effect.

Two level IV ecoregions in the Ridge and Valley ecoregion lie within the New River watershed. The Southern Limestone/Dolomite Valleys and Low Rolling Hills (67f) is a lowland characterized by broad, undulating, fertile valleys that are extensively farmed. Sinkholes, underground streams, and other karst features have developed on the underlying limestone/dolomite, and as a result, the drainage density is low. Where streams occur, they tend to have gentle gradients, plentiful year around flow, and distinctive fish assemblages. Crestal elevations vary from 1,640 to 3,200 feet (500 to 975 m). Local relief typically ranges from 150 to 500 feet (46 to 152 m).

Ordovician and Cambrian limestone and dolomite commonly underlie this ecoregion. Interbedded with the carbonates are other rocks, including shale, which gives the ecoregion topographic and soil diversity. Mesic Alfisols and Ultisols have developed from the rock.

The climate of Ecoregion 67f is well suited for agriculture and farming predominates, with scattered woodland occurring in steeper areas.

The Southern Shale Valleys (67g) ecoregion extends from the James River into Tennessee. It is characterized by rolling valleys and low hills and is underlain mostly by fine-grained rock. Local relief varies from about 125 feet to 650 feet (38 to 198 m). Woodland occurs on steeper sites and farming is common elsewhere.

The Brallier, Rome, Elbrook, Chemung, and Clinton formations commonly underlie Ecoregion 67g. They are folded and faulted, and are of Paleozoic age. The underlying rock is not as permeable as the limestone of the Ridge and Valley ecoregion 67, so surface streams are larger and drainage density is higher than in limestone areas. There is more soil erosion in Ecoregion 67g than in the Southern Limestone/ Dolomite Valleys and Low Rolling Hills (67f); stream turbidity can, therefore, be comparatively high and the riverine habitat relatively impaired.

Inceptisols and Ultisols have developed from residuum. Soils derived from acid shale commonly occur in Ecoregion 67g and are poorer than the soils of Ecoregion 67f, which were derived from limestone. However, within Ecoregion 67g there is considerable soil variability, and some soils are more calcareous than others (http://www.eoearth.org/article/Ecoregions_of_Delaware%2C_Maryland%2C_Pennsylvania%2C_Virginia%2C_and_West_Virginia_%28EPA%29).

As for the climatic conditions in the Little River watershed, during the period from 1933 to 2006 Floyd, Virginia (NCDC station# 443071) received an average annual precipitation of approximately 41.49 inches, with 54% of the precipitation occurring during the May through October growing season (SERCC, 2010). Average annual snowfall is 17.9 inches, with the highest snowfall occurring during January (SERCC, 2010). The highest average daily temperature of 82.2 ºF occurs in July, while the lowest average daily temperature of 23.1 ºF occurs in January (SERCC, 2010).

1.3 Little River Watershed Impairments

1.3.1 Little River (Bacteria, Benthic and Temperature)

The upper Little River was first listed as impaired for the Recreational Use on the *2004 303(d) TMDL Priority List* (VADEQ, 2004). The original fecal coliform listing was for segment VAW-N19R_LRV02A00. Two additional *E. coli* segments were added in the 2006 integrated report (VADEQ, 2006), which extended the impairment to a total of 33.55 miles. VAW-N19R_LRV01A00 begins at the confluence with the West Fork Little River and continues downstream to the Little River's confluence with Oldfield Creek (8.6 miles). VAW-N19R_LRV02A00 begins at the confluence with Oldfield

Creek and continues downstream to the Little River's confluence with Meadow Creek (10.91 miles). VAW-N19R_LRV03A00 begins at the Meadow Creek confluence and continues downstream to the Little River's confluence with Payne Creek (14.04 miles). During the 2008 assessment period four VADEQ ambient monitoring stations exceeded the instantaneous *E. coli* Water Quality Standard (WQS) of 235 cfu/100 mL more than 10.5% of the time. These stations are listed in Table 1.1.

Table 1.1 VADEQ *E. coli* violation rates during the 2008 assessment period.

VADEQ Monitoring Station	Number of Samples	Samples Exceeding WQS	% Violation Rate
9-LRV069.88	12	4	33.3
9-LRV065.57	11	4	36.4
9-LRV056.74	12	4	33.3
9-LRV044.49	11	3	27.3

Segment VAW-N19R_LRV02A00 was first listed for an Aquatic Life Use impairment on the 2002-303(d) list and segments VAW-N19R_LRV01A00 and VAW-N19R_LRV03A00 were added in 2008. All three segments lie within a natural trout waters designated section of the Little River. Natural trout waters have a maximum temperature standard of 20^0 Celsius.

The maximum natural trout waters temperature WQS (20^0 C) at three VADEQ ambient monitoring stations had a violation rate of more than 10.5%. These stations are listed in Table 1.2.

Table 1.2 VADEQ maximum temperature violation rates during the 2008 assessment period.

VADEQ Monitoring Station	Number of Samples	Samples Exceeding WQS	% Violation Rate
9-LRV065.57	12	2	16.7
9-LRV056.74	12	2	16.7
9-LRV044.49	12	2	16.7

Additional segments were listed for a bacteria impairment on the *2002 303(d) TMDL Priority List* (VADEQ, 2002). These segments are VAW-N21R_LRV03A00 (0.68 miles) and VAW-N21R_LRV04A00 (0.67 miles). The impairment began at the backwaters of the Little River Reservoir dam and continued upstream to the Little Rivers confluence with Meadow Creek. Five more segments were added on subsequent 303(d) lists for Recreational Use impairments. VAW-N21R_LRV01A00 (listed in 2004) begins at the New River confluence and continues upstream to the Little River Reservoir dam (0.69 miles). Segment VAW-N21R_LRV06A04 (listed in 2004) begins at the end of Rt 706 and continues downstream to the confluence with Sidney Creek. Segment VAW-N21R_LRV05A00 (listed in 2006) begins at the Meadow Creek confluence and continues upstream to the mouth of Big Indian Creek (12.22 miles). VAW-N21R_LRV06A00 (listed in 2006) begins at the confluence with Big Indian Creek and continues upstream to the natural trout waters designated section (8.01 miles). VAW-N21R_LRV07A00 (listed in 2006) begins at the end of natural trout waters designated section (at Rt 706) and continues upstream to Little River's confluence with the West Fork of the Little River (3.66 miles). The total length of the Recreational Use impairment is 39.05 stream miles. During the 2008 assessment period, six VADEQ ambient monitoring stations had more than 10.5% of the *E. coli* observations exceed the instantaneous WQS of 235 (cfu/100 mL) in these impaired segments. These stations are listed in Table 1.3.

Table 1.3 VADEQ *E. coli* violation rates during the 2008 assessment period.

VADEQ Monitoring Station	Number of Samples	Samples Exceeding WQS	% Violation Rate
9-LRV044.49	11	3	27.3
9-LRV032.72	11	4	36.4
9-LRV016.68	10	2	20.0
9-LRV009.11	11	2	18.2
9-LRV000.44	7	2	28.6
9-LRV000.34	14	4	28.6

Segments VAW-N21R_LRV06A04 and VAW-N21R_LRV07A00 were first listed on the *2008 303(d) TMDL Priority List* for an Aquatic Life Use impairment based on benthic macroinvertebrate monitoring at VADEQ benthic monitoring station 9-LRV035.03. A Virginia Stream Condition Index Score (VASCI) of 52.2 was recorded in the spring of 2004 (the impairment threshold is 60). Segment VAW-N21R_LRV07A00 lies within a natural trout waters designated section of the Little River. Natural trout waters have a maximum temperature standard of 20^0 Celsius.

1.3.2 Meadow Run (Bacteria and Benthic)

Meadow Run was first listed as impaired for Recreational Use impairment on the *2006 303(d) TMDL Priority List* (VADEQ, 2006). Meadow Run segment VAW-N19R_MDR01A04 begins at Meadow Run's headwaters and continues downstream to the Little River confluence (3.7 miles). During the 2008 assessment period VADEQ ambient monitoring station 9-MDR000.34 had more than 10.5% of the *E. coli* observations exceed the instantaneous WQS of 235 (cfu/100 mL) in the impaired segment.

Meadow Run was listed on the 2008 303(d) list for an Aquatic Life Use impairment. VADEQ benthic monitoring station 9-MDR003.60 had a VASCI score of 30.97 in the spring of 2001.

1.3.3 Pine Creek (Bacteria and Temperature)

Pine Creek was first listed with a Recreational Use impairment on the *2006 303(d) TMDL Priority List* (VADEQ, 2006). The impaired segment begins at a pond and continues downstream to Pine Creek's confluence with the Little River (3.68 miles). During the 2008 assessment period VADEQ ambient monitoring station 9-PNC000.69 had more than 10.5% of the *E. coli* observations exceed the instantaneous WQS of 235 (cfu/100 mL) in the impaired segment.

Pine Creek was listed for an Aquatic Life Use impairment on the *2008 303(d) TMDL Priority List* (VADEQ, 2008). During the 2008 assessment period VADEQ ambient monitoring station 9-PNC000.69 had more than 10.5% of the temperature observations exceed the maximum natural trout temperature WQS of 20^0C in the impaired segment. The Virginia Department of Game and Inland Fisheries (DGIF) classifies the natural trout waters designation in Pine Creek as:

> Class iii. Stream which contains a fair population of wild trout with carrying capacity depressed by natural factors or more commonly man-related land use practices. Land use activities may result in heavy siltation of the stream, destruction of banks and fish cover, water quality degradation, increased water temperature, etc. Most streams would be considered to be in the active state of degradation or recovery from degradation. Alteration in land use practices would generally improve carrying capacity of the stream (VADEQ WQS August 2009).

1.3.4 West Fork Dodd Creek (Temperature)

Impairment VAW-N20R_DDW01A02 begins at the confluence with Dodd Creek and continues upstream to the confluence with an unnamed tributary (1.17 miles). During the 2008 assessment period VADEQ ambient monitoring station 9-DDW000.02 had more than 10.5% of the temperature observations exceed the maximum natural trout temperature WQS of 20^0C in the impaired segment. The Virginia Department of Game and Inland Fisheries (DGIF) classifies the natural trout waters designation in the West Fork Dodd Creek as Class iii waters (see description for Pine Creek in section 1.3.3).

1.3.5 Dodd Creek (Temperature)

The impairment begins at the confluence with the West Fork Little River and continues upstream to the confluence with the West Fork of Dodd Creek (6.28 miles) and contains two segments, VAW-N20R_DDD01A00 and VAW-N20R_DDD02A00. During the 2008 assessment period VADEQ ambient monitoring stations 9-DDD002.62 and 9-DDD001.00 had more than 10.5% of the temperature observations exceed the maximum stockable trout temperature WQS of 21^0C in the impaired segment. The Virginia Department of Game and Inland Fisheries (DGIF) classifies the stockable trout waters designation in Dodd Creek as:

> Class vi. Stream does not contain a significant number of trout nor a significant population of warmwater gamefish. Water quality is adequate and water temperature good for summer carryover of stocked trout. Summer flow remains fair and adjacent land is not extensively developed. All streams in this class would be considered good trout stocking water (VADEQ WQS August 2009).

1.3.6 Big Indian Creek (Temperature)

The Big Indian Creek impaired segment (VAW-N21R_BIC01A02) begins 0.5 miles upstream from the confluence with the West Fork Indian Creek and continues downstream to Big Indian Creek's confluence with the Little River (7.56 miles). During the 2008 assessment period VADEQ ambient monitoring station 9-BIC000.14 had more than 10.5% of the temperature observations exceed the maximum stockable trout temperature WQS of 21^0C in the impaired segment. The Virginia Department of Game and Inland Fisheries (DGIF) classifies the stockable trout waters designation in Big Indian Creek as:

> Class v. Stream does not contain an adequately reproducing wild trout population nor does it have the potential for such. However, water quality is adequate, water temperature is good, and invertebrate productivity is exceptional. Pools are abundant with good size and depth and fish cover is excellent. Stream would be good for stocked trout but may offer more potential for a fingerling stocking program (VADEQ WQS August 2009).

1.3.7 Meadow Creek (Bacteria)

Meadow Creek was first listed as impaired for Recreational Use impairment on the *2002 303(d) TMDL Priority List* (VADEQ, 2002). The Meadow Creek impaired segment (VAW-MDW01A00) begins at the confluence with Mill Creek and continues downstream to Meadow Creek's confluence with the Little River (4.49 miles). During the 2004 assessment period VADEQ ambient monitoring station 9-MDW004.62 had more than 10.5% of the fecal coliform observations exceed the instantaneous WQS of 400 (cfu/100 mL) in the impaired segment.

1.3.8 Brush Creek (Bacteria)

Brush Creek was first listed as impaired for Recreational Use impairment on the *2004 303(d) TMDL Priority List* (VADEQ, 2004). The Brush Creek impaired segment (VAW-BSH01A04) begins at the Rt. 617 bridge and continues downstream to Brush Creek's confluence with the Little River (5.76 miles). During the 2004 assessment period VADEQ ambient monitoring station 9-BSH000.05 had more than 10.5% of the fecal coliform observations exceed the instantaneous WQS of 400 (cfu/100 mL) in the impaired segment.

1.3.9 Laurel Creek (Bacteria)

Laurel Creek was first listed as impaired for Recreational Use impairment on the *2004 303(d) TMDL Priority List* (VADEQ, 2004). The Laurel Creek impaired segment (VAW-LLL01A04) begins at the headwaters and continues downstream to Laurel Creek's confluence with the Little River (3.26 miles). During the 2004 assessment period VADEQ ambient monitoring station 9-LLL000.05 had more than 10.5% of the fecal coliform observations exceed the instantaneous WQS of 400 (cfu/100 mL) in the impaired segment.

The USEPA approved bacterial TMDLs on June 5, 2002 and December 11, 2002 for Mill and Dodd Creeks respectively, which are located within the study area. (https://www.deq.virginia.gov/TMDLDataSearch/ReportSearch.jspx). Figure 1.2 shows all the impairments addressed in the current project.

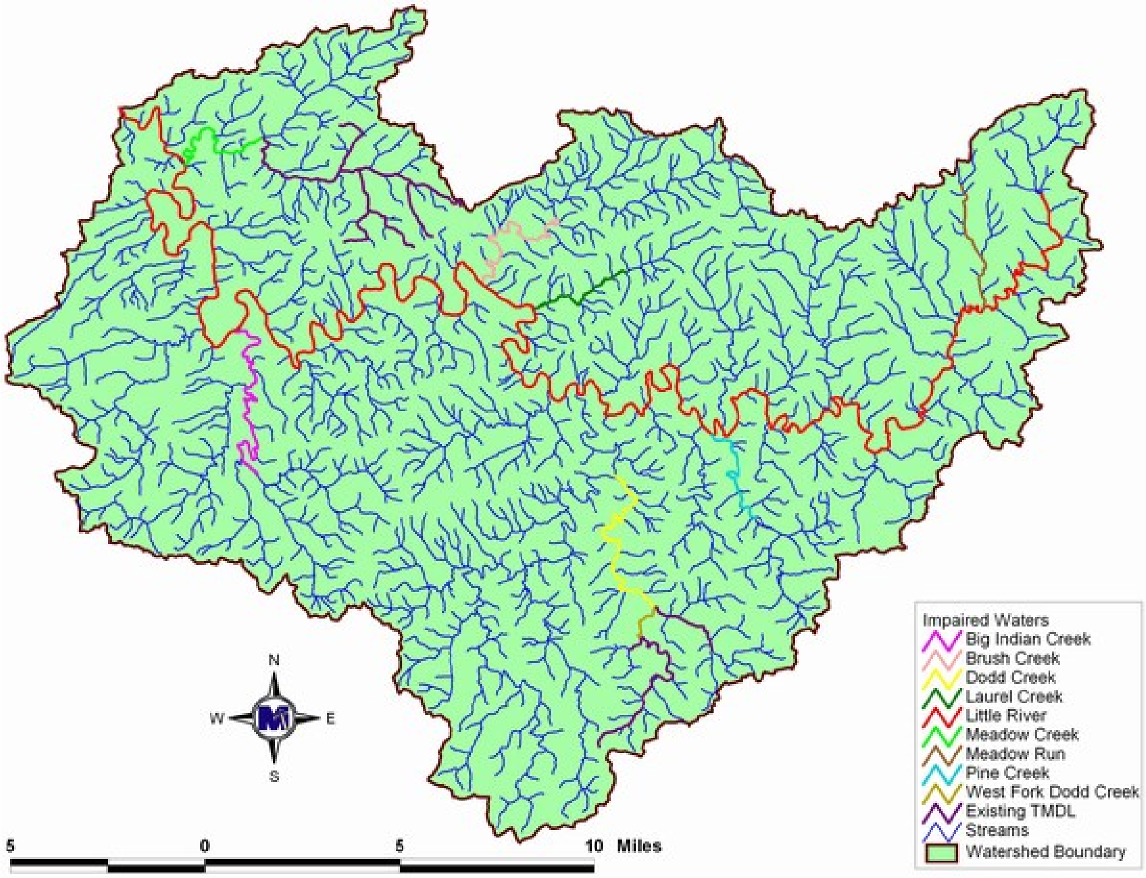

Figure 1.2 The impaired segments within the Little River watershed included in this project.

Table 1.4 Impairments within the Little River watershed.

Stream Name Assessment Unit Id	**Impairment Contracted**	**Initial Listing Year**	**2008 River Miles**	**2008 Listing Violation[1] Rates**	**Impairment Location Description**
Little River VAW-N19R_LRV01A00	Bacteria	2006	8.60	27.3	Confluence with Oldfield Creek downstream to the confluence with West Fork Little River.
Little River VAW-N19R_LRV01A00	Temperature	2008		16.7[1]	
Little River VAW-N19R_LRV02A00	Bacteria	2006	10.91	33.3	Confluence with Meadow Creek downstream to the confluence with Oldfield Creek.
Little River VAW-N19R_LRV02A00	Temperature	2002		16.7[1]	
Little River VAW-N19R_LRV03A00	Bacteria	2006	14.04	36.4 33.3	Confluence with Payne Creek downstream to the confluence with Meadow Creek.
Little River VAW-N19R_LRV03A00	Temperature	2008		16.7[1]	
Little River VAW-N21R_LRV06A04	Bacteria	2004	13.33	36.4[2]	End of Rt. 706 downstream to the confluence with Sidney Creek.
Little River VAW-N21R_LRV06A04	Benthic	2008		NA	
Little River VAW-N21R_LRV07A00	Bacteria	2006	3.66	27.3	West Fork Little River confluence downstream to the WQS natural trout waters designation.
Little River VAW-N21R_LRV07A00	Benthic	2008		NA	
Little River VAW-N21R_LRV01A00	Bacteria	2004	0.48	28.6[2]	Little River Reservoir dam downstream to the New River confluence.
Little River VAW-N21R_LRV03A00	Bacteria	2002	0.68	28.6[2]	PWS designated section for Radford downstream to the backwaters of the Little River Reservoir.

[1] Temperature impairment based on the natural trout maximum temperature WQS of 20^{0}C.
Bacteria impairments are based on the instantaneous *E. coli* WQS of 235 cfu/100mL for samples collected during the most recent data period assessment unless otherwise noted.
[2] Based on the instantaneous fecal coliform WQS of 400 cfu/100mL .

Table 1.4 Impairments within the Little River watershed (cont.).

Stream Name Impairment Id	**Impairment Contracted**	**Initial Listing Year**	**2008 River Miles**	**2008 Listing Violations/ Total Samples**	**Impairment Location Description**
Little River VAW-N21R_LRV04A00	Bacteria	2002	0.67	4/14[2]	Confluence with Meadow Creek downstream to the PWS section.
Little River VAW-N21R_LRV05A00	Bacteria	2006	12.22	2/11[2]	Big Indian Creek confluence downstream to the Meadow Creek confluence.
Little River VAW-N21R_LRV06A00	Bacteria	2006	8.01	2/10[2]	WQS natural trout waters section downstream to the confluence with Big Indian Creek.
Little River (Reservoir) VAW-N21L_LRV01A02	Bacteria	2008	60.44[1]	2/7[2]	From the reservoir backwaters to the dam.
Meadow Run VAW-N19R_MDR01A04	Bacteria	2006	3.70	4/12	From the headwaters downstream to the confluence with Little River.
Meadow Run VAW-N19R_MDR01A04	Benthic	2008		NA	
Pine Creek VAW-N19R_PNC01A06	Bacteria	2006	3.68	3/11	From the impounding structure of a pond downstream to the Little River confluence.
Pine Creek VAW-N19R_PNC01A06	Temperature	2008		2/12[3]	
West Fork Dodd Creek VAW-N20R_DDW01A02	Temperature	2002	1.17	2/2[3]	From an unnamed tributary downstream the confluence with Dodd Creek.
Dodd Creek VAW-N20R_DDD01A00	Temperature	2008	3.78	2/9[4] 2/9[4]	Floyd County PSA outfall downstream to the West Fork Little River confluence.
Dodd Creek VAW-N20R_DDD02A00	Temperature	2008	2.50	1/2[4] 1/1[4]	West Fork Dodd Creek confluence downstream to the Floyd County PSA outfall.

Bacteria impairments are based on the instantaneous *E. coli* WQS of 235 cfu/100mL for samples collected during the most recent data period assessment unless otherwise noted

[1] acres

[2] Based on the instantaneous fecal coliform WQS of 400 cfu/100mL .

[3] Based on the natural trout maximum temperature WQS of 20^0C

[4] Based on the stockable trout maximum temperature WQS of 21^0C

Table 1.4 Impairments within the Little River watershed (cont.).

Stream Name Impairment Id	**Impairment Contracted**	**Initial Listing Year**	**2008 River Miles**	**2008 Listing Violations[1]/ Total Samples**	**Impairment Location Description**
Meadow Creek VAW-N21R_MDW01A00	Bacteria	2002	4.49	7/12[1]	From the Mill Creek confluence downstream to the Little River confluence.
Brush Creek VAW-N21R_BSH01A04	Bacteria	2004	5.76	5/10[1]	From the Rt. 617 bridge downstream to the Little River confluence.
Laurel Creek VAW-N21R_LLL01A04	Bacteria	2004	3.26	5/10[1]	From its headwaters downstream to the Little River confluence.
Big Indian Creek VAW-N21R_BIC01A02	Temperature	2004	7.56	2/11[2]	0.5 miles upstream from the West Fork Big Indian Creek confluence downstream to the confluence with Little River.

[1] Based on the instantaneous fecal coliform standard of 400 cfu/100mL or the instantaneous during the 2004 assessment cycle.
[2] Based on sampling during the 2004 assessment cycle, the results are based on the stockable trout maximum temperature WQS of 21^0C.

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2. BACTERIAL TMDL ENDPOINT AND WATER QUALITY ASSESSMENT

2.1 Applicable Water Quality Standards

According to 9 VAC 25-260-5 of Virginia's State Water Control Board *Water Quality Standards*, the term "water quality standards" means "…provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law and the federal Clean Water Act".

As stated in Virginia state law 9 VAC 25-260-10 (Designation of uses),

> *A. All state waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish.*
>
> ♦
>
> *D. At a minimum, uses are deemed attainable if they can be achieved by the imposition of effluent limits required under §§301(b) and 306 of the Clean Water Act and cost-effective and reasonable best management practices for nonpoint source control.*

2.2 Applicable Criteria for Fecal Bacteria Impairments

Virginia adopted its current *E. coli* and *enterococci* standard in January 2003 and was updated in 2009. *E. coli* and *enterococci* are both bacteriological organisms that can be found in the intestinal tract of warm-blooded animals; there is a strong correlation between these and the incidence of gastrointestinal illness. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination.

The criteria which were used in developing the bacteria TMDL in this study are outlined in Section 9 VAC 25-260-170 (Bacteria; other recreational waters) and read as follows:

A. The following bacteria criteria (colony forming units (cfu)/100mL) shall apply to protect primary contact recreational uses in surface waters, except waters identified in subsection B of this section:

E. coli bacteria shall not exceed a monthly geometric mean of 126 cfu/100mL in freshwater. Enterococci bacteria shall not exceed a monthly geometric mean of 35 cfu/100mL in transition and saltwater.

1. *See 9VAC25-260-140 C for boundary delineations for freshwater, transition and saltwater.*
2. *Geometric means shall be calculated using all data collected during any calendar month with a minimum of four weekly samples.*
3. *If there [are] insufficient data to calculate monthly geometric means in freshwater, no more than 10% of the total samples in the assessment period shall exceed 235 E. coli cfu/100mL.*
4. *If there [are] insufficient data to calculate monthly geometric means in transition and saltwater, no more than 10% of the total samples in the assessment period shall exceed enterococci 104 cfu/100mL.*
5. *For beach advisories or closures, a single sample maximum of 235 E. coli cfu/100mL in freshwater and a single sample maximum of 104 enterococci cfu/100mL in saltwater and transition zones shall apply.*

B. The following bacteria criteria per 100mL (cfu/100mL) of water shall apply to protect secondary contact recreational uses in surface waters:

E. coli bacteria shall not exceed a monthly geometric mean of 630 cfu/100mL in freshwater. Enterococci bacteria shall not exceed a monthly geometric mean of 175 cfu/100mL in transition and saltwater.

1. *See 9VAC25-260-140 C for boundary delineations for freshwater, transition and saltwater.*
2. *Geometric means shall be calculated using all data collected during any calendar month with a minimum of four weekly samples.*
3. *If there [are] insufficient data to calculate monthly geometric means in freshwater, no more than 10% of the total samples in the assessment period shall exceed 1173 E. coli cfu/100mL.*
4. *If there [are] insufficient data to calculate monthly geometric means in transition and saltwater, no more than 10% of the total samples in the assessment period shall exceed enterococci 519 cfu/100mL.*
5. *Where the existing water quality for bacteria is below the geometric mean criteria in a water body designated for secondary contact in subdivision 6 of this subsection that higher water quality will be maintained in accordance with 9VAC25-260-30 A 2.*

2.3 Selection of a Bacteria TMDL Endpoint

The first step in developing a TMDL is the establishment of in-stream numeric endpoints, which are used to evaluate the attainment of acceptable water quality. In-stream numeric endpoints, therefore, represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. For the bacteria impairments in the Little River watershed, the applicable endpoints and associated target values can be determined directly from the Virginia water quality regulations. In order to remove a waterbody from a state's list of impaired waters, the Clean Water Act requires compliance with that state's water quality standard.

Since modeling provided simulated output of *E. coli* concentrations at 1-hour intervals, assessment of TMDLs was made using the geometric mean standard. Therefore, the in-stream *E. coli* target for the TMDLs in this study was a monthly geometric mean not exceeding 126 cfu/100 mL.

2.4 Discussion of In-Stream Water Quality

This section provides an inventory and analysis of available observed in-stream fecal bacteria monitoring data in the Little River watershed. An examination of data from water quality stations used in the 303(d) assessment was performed. Sources of data and pertinent results are discussed.

2.4.1 Inventory of Water Quality Monitoring Data

The primary sources of available fecal bacteria information are:

- Bacteria enumerations from 17 VADEQ in-stream monitoring stations with date from January 1990 to December 2009.

2.4.1.1 VADEQ Water Quality Monitoring for TMDL Assessment

Data from in-stream water samples, collected at VADEQ monitoring stations from January 1990 to November 2009 (Figure 2.1) were analyzed for fecal coliform (Table 2.1). Samples were taken for the express purpose of determining compliance with the state instantaneous standard limiting fecal coliform concentrations to 400 cfu/100 mL. As a matter of economy, samples showing fecal coliform concentrations below 100 cfu/100 mL or in excess of a specified cap (*e.g.,* 8,000 or 16,000 cfu/100 mL, depending on the laboratory procedures employed for the sample) were not analyzed further to determine the precise concentration of fecal coliform bacteria. The result is that reported values of 100 cfu/100 mL most likely represent concentrations below 100 cfu/100 mL, and reported concentrations of 8,000 or 16,000 cfu/100 mL most likely represent concentrations in excess of these values.

E. coli samples were also collected to evaluate compliance with the state's current bacterial standard. Table 2.2 summarizes the *E. coli* samples collected at the in-stream monitoring stations. Information in the tables is arranged in alphabetical order by stream name then from downstream to upstream station location.

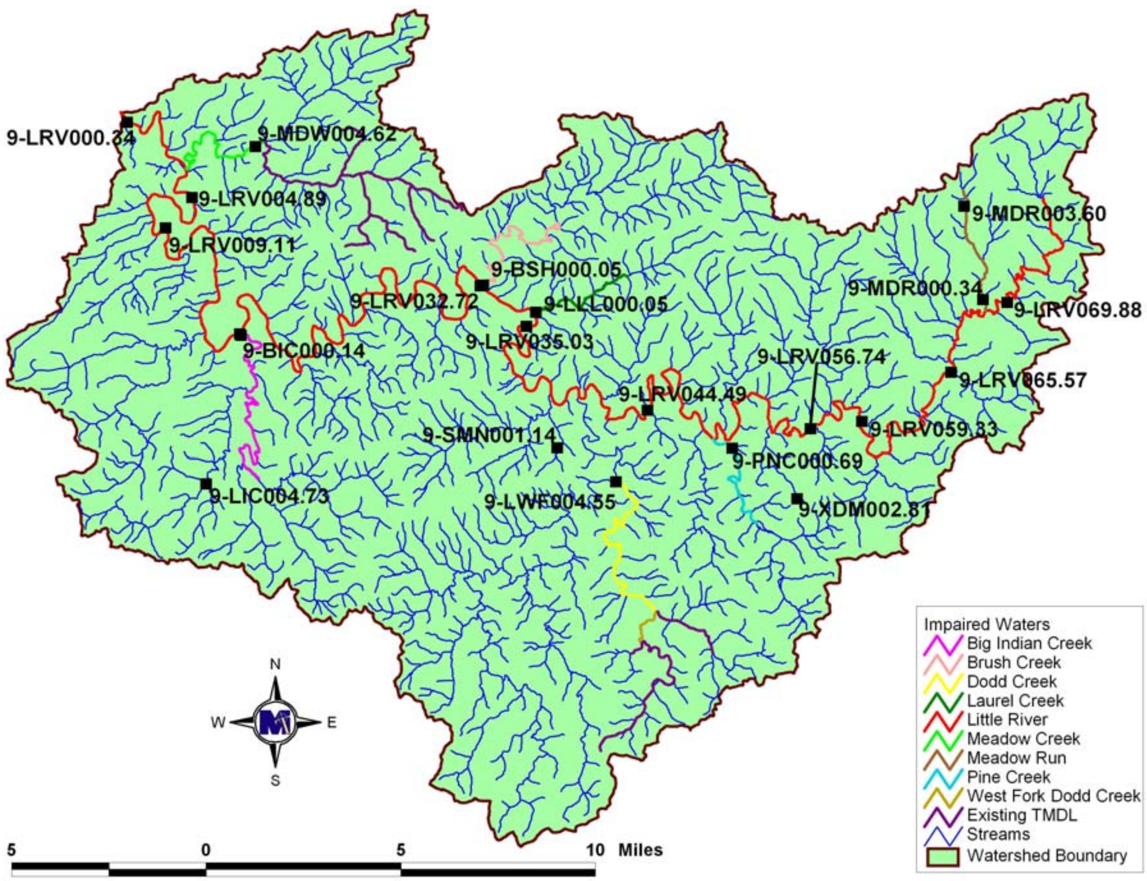

Figure 2.1 Location of VADEQ bacteria water quality monitoring stations in the Little River watershed.

Table 2.1 Summary of fecal coliform (cfu/100mL) data collected by VADEQ from January 1990 – November 2009.

Stream	Station	Date	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Violation[1] %
Brush Creek	9-BSH000.05	07/01 - 05/03	10	100	1,300	540	550	448	50.0%
Laurel Creek	9-LLL000.05	07/01 - 05/03	10	100	2,800	670	400	833	50.0%
Little River	9-LRV000.34	01/90 - 05/03	58	100	7,300	617	100	1,508	20.7%
Little River	9-LRV004.89	05/03	1	25	25	25	NA	NA	0.0%
Little River	9-LRV009.11	07/01 - 11/09	17	25	820	239	100	233	23.5%
Little River	9-LRV016.68	07/01 - 05/03	10	100	8,000	990	100	2,475	20.0%
Little River	9-LRV032.72	07/01 - 05/03	11	100	3,300	609	200	951	36.4%
Little River	9-LRV035.03	04/04	1	130	130	130	NA	NA	0.0%
Little River	9-LRV059.33	11/96 - 05/00	16	100	1,400	288	200	324	12.5%
Meadow Run	9-MDR003.60	11/01	1	900	900	900	NA	NA	100.0%
Meadow Creek	9-MDW004.62	07/01 - 05/03	11	100	8,000	1,418	700	2,279	54.5%

NA – Not applicable

[1] Based on the instantaneous fecal coliform standard of 400 cfu/100mL.

Table 2.2 Summary of *E. coli* (cfu/100mL) data collected by VADEQ from August 2003 – December 2009.

Stream	Station	Date	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Violation[1] %
Brush Creek	9-BSH000.05	02/09 - 12/09	5	25	2,000	625	200	817	40.0%
Laurel Creek	9-LLL000.05	02/09 - 12/09	5	50	1,000	430	200	419	40.0%
Little River	9-LRV000.34	01/07 - 11/08	12	25	2,000	242	25	566	8.3%
Little River	9-LRV004.89	05/05	1	10	10	10	NA	NA	0.0%
Little River	9-LRV009.11	01/09 - 11/09	6	25	1,000	304	150	365	16.7%
Little River	9-LRV016.68	01/09 - 11/09	6	25	1,200	322	150	450	16.7%
Little River	9-LRV035.03	04/04	1	10	10	10	NA	NA	0.0%
Little River	9-LRV044.49	08/03 - 06/05	11	25	2,000	309	75	581	18.2%
Little River	9-LRV056.74	08/03 - 06/05	12	25	2,000	351	190	543	16.7%
Little River	9-LRV065.57	08/03 - 12/09	16	25	1,800	335	75	478	31.3%
Little River	9-LRV069.88	08/03 - 06/05	12	25	1,500	312	175	411	25.0%
Meadow Run	9-MDR000.34	08/03 - 12/09	17	25	2,000	489	200	550	41.2%
Meadow Creek	9-MDW004.62	01/07 - 11/08	12	25	2,000	520	250	656	25.0%
Pine Creek	9-PNC000.69	08/03 - 06/05	11	25	1,000	221	50	300	18.2%

NA – Not applicable

[1] Based on the current instantaneous *E. coli* standard of 235 cfu/100mL.

3. BACTERIAL SOURCE ASSESSMENT

The TMDL development described in this report includes examination of all potential sources of fecal bacteria in the Little River watershed. The source assessment was used as the basis of model development and ultimate analysis of TMDL allocation options. In evaluation of the sources, loads were characterized by the best available information, landowner input, literature values, and local management agencies. This section documents the available information and interpretation for the analysis. The source assessment chapter is organized into permitted and nonpoint sections. The representation of the following sources in the model is discussed in Chapter 4.

3.1 Assessment of Permitted Sources

There are two VPDES permited discharges in the Little River watershed but both of them are in portions of the watershed with already approved TMDLs and therefore will not be considered in the modeling for this TMDL study. The location of the dischargs in the waterhsed is shown in Figure 3.1.

Table 3.1 shows the single family home permits within the Little River watershed. These permits allow treated residential wastewater to be discharged to surface waters. All of these housing units discharge water and bacteria to the streams. Currently, these permitted discharges are expected not to exceed the 126 cfu/100mL *E. coli* geometric mean standard. One method for achieving this goal is chlorination. Chlorine is added to the discharge stream at levels intended to kill pathogens. The use of "UT" refers to unnamed tributaries.

Table 3.1 Single family home permits in the Little River watershed.

Permit	Receiving Stream	Facility Type
VAG402042	Big Run Creek	Domestic
VAG402018	UT to Big Run Creek	Domestic
VAG402051	UT to Meadow Run	Domestic
VAG402090	UT to Little River	Domestic

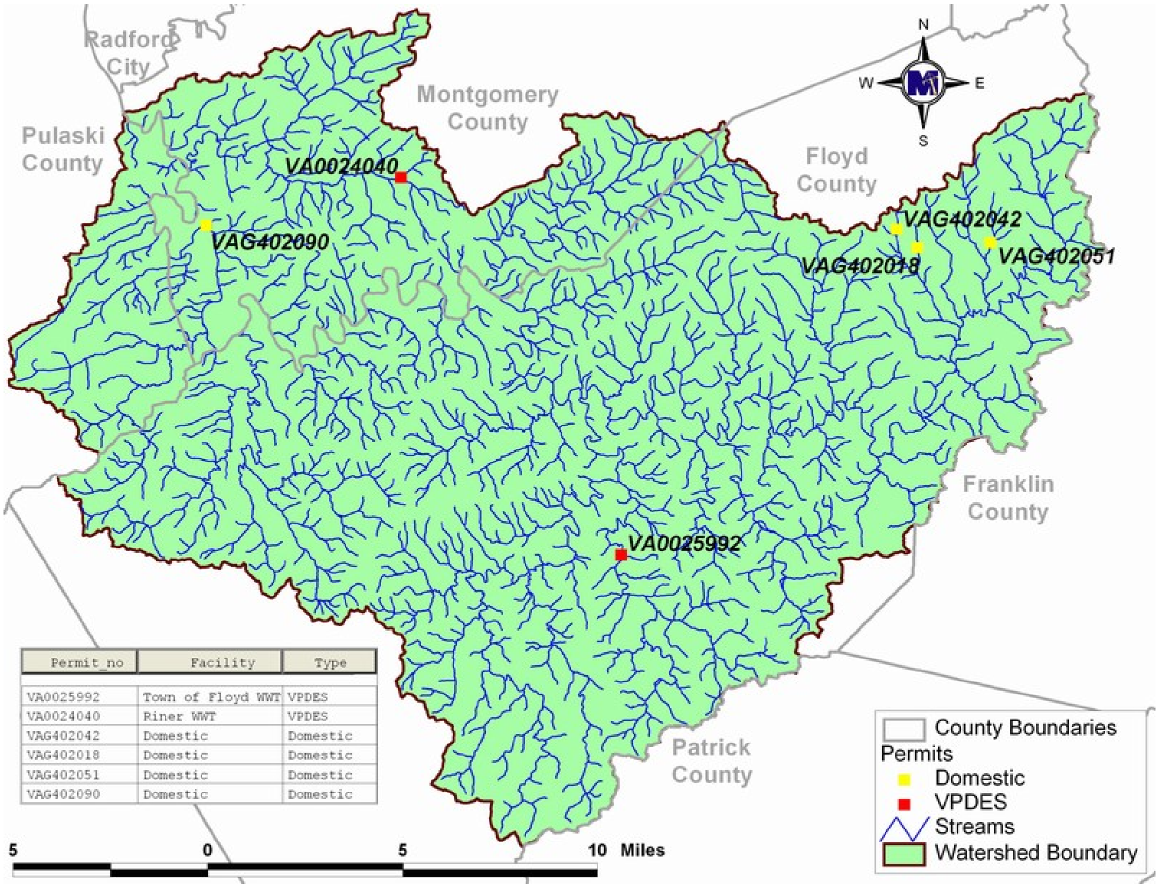

Figure 3.1 Location of VADEQ permits in the Little River watershed.

3.2 Assessment of Nonpoint Sources

In the Little River watershed, both urban and rural nonpoint sources of fecal coliform bacteria were identified and enumerated. Sources include residential sewage treatment systems, land application of waste (livestock and biosolids), livestock, wildlife, and pets. MapTech previously collected samples of fecal coliform sources (*i.e.*, wildlife, livestock, pets, and human waste) and enumerated the density of fecal coliform bacteria. This analysis was used to support the modeling process for the current project. Where appropriate, spatial distribution of sources was also determined.

3.2.1 Private Residential Sewage Treatment

Population, housing units, and type of sewage treatment data from the U.S. Census Bureau were determined using GIS (Table 3.2). In the U.S. Census questionnaires, housing occupants were asked which type of sewage disposal existed. Houses can be connected to a public sanitary sewer, a septic tank, or a cesspool, or the sewage is disposed of in some other way. The Census category “Other Means” includes the houses that dispose of sewage other than by public sanitary sewer or a private septic system. The houses included in this category are assumed to be disposing of sewage via a straight pipe (uncontrolled discharge).

Sanitary sewers are piping systems designed to collect wastewater from individual homes and businesses and carry it to a wastewater treatment plant. Sewer systems are designed to carry a specific "peak flow" volume of wastewater to the treatment plant. Within this design parameter, sanitary collection systems are not expected to overflow, surcharge or otherwise release sewage before their waste load is successfully delivered to the wastewater treatment plant.

When the flow of wastewater exceeds the design capacity or the capacity is reduced by a blockage, the collection system will "back up" and sewage discharges through the nearest escape location. These discharges into the environment are called overflows. Wastewater can also enter the environment through exfiltration caused by line cracks, joint gaps, or breaks in the piping system.

Typical private residential sewage treatment systems (septic systems) consist of a septic tank, distribution box, and a drainage field. Waste from the household flows first to the septic tank, where solids settle out and are periodically removed by a septic tank pump-out. The liquid portion of the waste (effluent) flows to the distribution box, where it is distributed among several buried, perforated pipes that comprise the drainage field. Once in the soil, the effluent flows downward to groundwater, laterally to surface water, and/or upward to the soil surface. Removal of fecal bacteria is accomplished primarily by die-off during the time between introduction to the septic system and eventual introduction to naturally occurring waters. Properly designed, installed, and functioning septic systems contribute virtually no fecal bacteria to surface waters.

A septic failure occurs when a drain field has inadequate drainage or a "break", such that effluent flows directly to the soil surface, bypassing travel through the soil profile. In this situation, the effluent is either available to be washed into waterways during runoff events or is directly deposited in-stream due to close proximity. A survey of septic pump-out contractors, previously performed by MapTech, showed that failures were more likely to occur in the winter-spring months than in the summer-fall months, and that a higher percentage of system failures were reported because of a back-up to the household than because of a failure noticed in the yard.

MapTech previously sampled waste from septic tank pump-outs and found an average fecal coliform density of 1,040,000 cfu/100 mL. An average fecal coliform density for human waste of 13,000,000 cfu/g and a total waste load of 75 gal/day/person was reported by Geldreich (1978).

Table 3.2 Human population information for 2011 in areas contributing to impaired segments in the Little River watershed.

Population	Housing Units	Sanitary Sewer	Septic Systems	Other *
15,120	7,107	485	6,265	357

* Houses with sewage disposal systems other than sanitary sewer and septic systems.

3.2.2 Biosolids

Biosolids were applied within three sites in the Little River study area (Table 3.3). The source of biosolids was the Town of Christiansburg Waste Water Treatment facility. Records of applications obtained from VADEQ show that the total amount of biosolids applied was 1,232 tons between 2004 and 2009. The task of regulating biosolids application in Virginia was transferred in 2007 from the Virginia Department of Health to the Virginia Department of Environmental Quality. Biosolids are required to be spread according to sound agronomic requirements with consideration for topography and hydrology. Class B biosolids may not have a fecal coliform density greater than 1,995,262 cfu/g (total solids). Application rates must be limited to a maximum of 15 dry tons/acre per three-year period. Farms with applied biosolids must also have approved nutrient management plans, which call for a non-application buffer between fields and streams.

Table 3.3 Application of biosolids within the Little River study area (2004 – 2009).

Impairment	Tons
Little River	1,232

3.2.3 Pets

Among pets, cats and dogs are the predominant contributors of fecal coliform in the Little River watershed and were the only pets considered in this analysis. Cat and dog populations were derived from American Veterinary Medical Association Center for Information Management demographics in 1997. Dog waste load was reported by Weiskel et al. (1996), while cat waste load was previously measured by MapTech. Fecal coliform density for dogs and cats was previously measured from samples collected by MapTech. A summary of the data collected is given in Table 3.4. Table 3.5 lists the domestic animal populations for impairments in the Little River watershed.

Table 3.4 Domestic animal population density, waste load, and fecal coliform density.

Type	Population Density (an/house)	Waste load (g/an-day)	FC Density (cfu/g)
Dog	0.534	450	480,000
Cat	0.598	19.4	9

Table 3.5 Estimated domestic animal populations in areas contributing to impaired segments in the Little River watershed.

Dogs	Cats
3,381	3,786

3.2.4 Livestock

The predominant types of livestock in the Little River watershed are beef cattle, dairy, and horses, although all types of livestock identified were considered in modeling the watersheds. Table 3.6 gives a summary of livestock populations in the Little River watershed for 2011. Animal populations were based on communication with VADEQ, Virginia Cooperative Extension Service (VCE), Virginia Department of Conservation and Recreation (VADCR), Skyline Soil and Water Conservation District (SSWCD), watershed visits, and verbal communication with citizens at the first public meeting.

Table 3.6 Livestock populations (2011) in areas contributing to impaired segments in the Little River watershed.

Beef Adult	Beef Calves	Dairy Milkers	Dairy Dry	Dairy Calves	Horse	Sheep
21,225	26,477	568	284	284	1,089	1,788

Values of fecal coliform density of livestock sources were based on sampling previously performed by MapTech (MapTech, 1999). Reported manure production rates for livestock were taken from American Society of Agricultural Engineers (1998). A summary of fecal coliform density values and manure production rates is presented in Table 3.7.

Table 3.7 Average fecal coliform densities and waste loads associated with livestock.

Type	Waste Load (lb/d/an)	Fecal Coliform Density (cfu/g)	Waste Storage Die-off factor
Beef stocker (850 lb)	51.0	101,000	NA
Beef calf (350 lb)	21.0	101,000	NA
Dairy milker (1,400 lb)	120.4	271,329	0.5
Dairy heifer (850 lb)	70.0	271,329	0.25
Dairy calf (350 lb)	29.0	271,329	0.5
Hog (135 lb)	11.3	400,000	0.8
Hog Lagoon	N/A	95,300[1]	NA
Horse (1,000 lb)	51.0	94,000	NA
Sheep (60 lb)	2.4	43,000	NA
Goat (140 lb)	5.7	15,000	NA
Poultry (1 lb):			
Broiler	0.17	586,000	0.5
Layer	0.26	586,000	0.5

[1]units are cfu/100ml

Fecal coliform produced by livestock can enter surface waters through four pathways. First, waste produced by animals in confinement is typically collected, stored, and applied to the landscape (*e.g.,* pasture and cropland), where it is available for wash-off during a runoff-producing rainfall event. Second, grazing livestock deposit manure directly on the land, where it is available for wash-off during a runoff-producing rainfall event. Third, livestock with access to streams occasionally deposit manure directly in streams. Fourth, some animal confinement facilities have drainage systems that divert wash-water and waste directly to drainage ways or streams. Table 3.8 shows the average percentage of collected livestock waste that is applied throughout the year.

The percentage of time spent on pasture for beef cattle is given in Table 3.9. Horses and sheep were assumed to be in pasture 100% of the time. The average amount of time spent by beef cattle in stream access areas (*i.e.*, within 50 feet of the stream) for each month is given in Table 3.9.

Table 3.8 Average percentage of collected livestock waste applied throughout year.

Month	Applied % of Total	Land use
	Dairy	
January	2.00	Cropland
February	2.00	Cropland
March	20.00	Cropland
April	20.00	Cropland
May	5.00	Cropland
June	2.00	Pasture
July	2.00	Pasture
August	2.00	Pasture
September	21.00	Cropland
October	20.00	Cropland
November	2.00	Cropland
December	2.00	Cropland

Table 3.9 Average time beef cows not confined in feedlots spend in pasture and stream access areas per day for the Little River watershed.

Month	Pasture (hr)	Stream Access (hr)
January	23.3	0.7
February	23.3	0.7
March	23.0	1.0
April	22.6	1.4
May	22.6	1.4
June	22.3	1.7
July	22.3	1.7
August	22.3	1.7
September	22.6	1.4
October	23.0	1.0
November	23.0	1.0
December	23.3	0.7

3.2.5 Wildlife

The predominant wildlife species in the Little River watershed were determined through consultation with wildlife biologists from the Virginia Department of Game and Inland Fisheries (VDGIF) and United States Fish and Wildlife Service (FWS). Population densities were calculated from data provided by VDGIF and FWS and are listed in Table 3.10 (Bidrowski, 2004; Farrar, 2003; Fies, 2004; Knox, 2004; Norman, 2004; Raftovich, 2004; Rose and Cranford, 1987; Mayhorn, 2005).

Table 3.10 Wildlife population densities for the Little River watershed.

Deer (an/ac of habitat)	Turkey (an/ac of habitat)	Goose (an/ac of habitat)	Duck (an/ac of habitat)	Muskrat (an/ac of habitat)	Raccoon (an/ac of habitat)	Beaver (an/mi of stream)
0.003439	0.009066	0.003197	0.006515	2.7512	0.070342	3.8

The numbers of animals estimated in the Little River watershed are reported in Table 3.11.

Table 3.11 Estimated wildlife populations in the Little River watershed.

Raccoon	Muskrat	Deer	Goose	Turkey	Duck	Beaver
14,082	63,619	6,865	74	1,742	151	1,567

Where available, fecal coliform densities were based on sampling of wildlife scat performed previously by MapTech. The only value that was not obtained from MapTech sampling in the watershed was for beaver. The fecal coliform density of beaver waste was taken from sampling done for the Mountain Run TMDL development (Yagow, 1999). Percentage of time spent in stream access areas and percentage of waste directly deposited to streams was based on habitat information and location of feces during source sampling. Fecal coliform densities and estimated percentages of time spent in stream access areas (*i.e.*, within 100 feet of stream) are reported in Table 3.12.

Table 3.12 Average fecal coliform densities and percentage of time spent in stream access areas for wildlife.

Animal Type	Fecal Coliform Density (cfu/g)	Portion of Day in Stream Access Areas (%)
Raccoon	2,100,000	5
Muskrat	1,900,000	90
Beaver	1,000	100
Deer	380,000	5
Turkey	1,332	5
Goose	250,000	50
Duck	3,500	75

Table 3.13 summarizes the habitat and waste production information for wildlife. Waste loads were comprised from literature values and discussion with VDGIF personnel (ASAE, 1998; Bidrowski, 2003; Costanzo, 2003; and Weiskel et al., 1996). Habitat was determined based on information obtained from The Fire Effects Information System (1999) and VDGIF (Costanzo, 2003; Norman, 2003; Rose and Cranford, 1987; and VDGIF, 1999).

Table 3.13 Wildlife fecal production rates and habitat.

Animal	Waste Load (g/an-day)	Habitat
Raccoon	450	**Primary** = region within 600 ft of perennial streams **Secondary** = region between 601 and 7,920 ft from perennial streams **Infrequent/Seldom** = rest of watershed area including waterbodies (lakes, ponds)
Muskrat	100	**Primary** = waterbodies, and land area within 66 ft from the edge of perennial streams, and waterbodies **Secondary** = region between 67 and 308 ft from perennial streams, and waterbodies **Infrequent/Seldom** = rest of the watershed area
Beaver[1]	200	**Primary** = Perennial streams. Generally flat slope regions (slow moving water), food sources nearby (corn, forest, younger trees) **Infrequent/Seldom** = rest of the watershed area
Deer	772	**Primary** = forest, harvested forest land, orchards, grazed woodland, urban grassland, cropland, pasture, livestock access, wetlands, transitional land, reclaimed mine land **Secondary** = low density residential, medium density residential, gas wells, abandoned mine land **Infrequent/Seldom** = water, barren, high-density residential, commercial/industrial/transportation, active mine land, developed
Turkey[2]	320	**Primary** = forest, harvested forest land, grazed woodland, orchards, wetlands, transitional land, reclaimed mine land **Secondary** = cropland, pasture **Infrequent/Seldom** = water, barren, residential, developed, abandoned mine land, commercial/industrial/transportation, active mine land, gas wells
Goose[3]	225	**Primary** = waterbodies, and land area within 66 ft from the edge of water **Secondary** = region between 67 and 308 ft from water **Infrequent/Seldom** = rest of the watershed area
Mallard (Duck)	150	**Primary** = waterbodies, and land area within 66 ft from the edge of water **Secondary** = region between 67 and 308 ft from water **Infrequent/Seldom** = rest of the watershed area

[1] Beaver waste load was calculated as twice that of muskrat, based on field observations.
[2] Waste load for domestic turkey (ASAE, 1998).
[3] Goose waste load was calculated as 50% greater than that of duck, based on field observations and conversation with Gary Costanzo (Costanzo, 2003)

4. BACTERIA MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Establishing the relationship between in-stream water quality and the source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired water quality endpoint. In the development of TMDLs in the Littler River study area, this relationship was defined through computer modeling based on data collected throughout the watersheds. Monitored flow and water quality data were then used to verify that the relationships developed through modeling were accurate. There are five basic steps in the development and use of a water quality model: model selection, source assessment, selection of a representative modeling period, model calibration, model validation, and model simulation.

Model selection involves identifying an approved model that is capable of simulating the pollutants of interest with the available data. Source assessment involves identifying and quantifying the potential sources of pollutants in the watershed. Selection of a representative period involves the identification of a time period that accounts for critical conditions associated with all potential sources within the watershed. Calibration is the process of comparing modeled data to observed data and making appropriate adjustments to model parameters to minimize the error between observed and simulated events. Validation is the process of comparing modeled data to observed data during a period other than that used for calibration, with the intent of assessing the capability of the model in hydrologic conditions other than those used during calibration. During validation, no adjustments are made to model parameters. Once a suitable model is constructed, the model is then used to predict the effects of current loadings and potential management practices on water quality.

The USGS Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to simulate streamflow, overland runoff and to perform bacteria TMDL allocations. Hydrologic parameters collected for the watershed were used to calibrate and validate the simulated flow. The sources of bacteria in the watershed were identified and quantified and then used to calibrate the model's simulation using observed data collected by VADEQ. Existing conditions of bacteria were then entered into the model to simulate the baseline conditions. This stage gives an indication of the current, predicted, violation rates of the geometric mean standard. At this point, the model was used in the allocation process where reductions are simulated for various sources until the bacteria geometric mean standard was met. Details of all the modeling procedures are presented in Appendix B.

5. BACTERIAL ALLOCATION

Total Maximum Daily Loads (TMDLs) consist of waste load allocations (WLAs, permitted sources) and load allocations (LAs, non-permitted sources) including natural background levels. Additionally, the TMDL must include a margin of safety (MOS) that either implicitly or explicitly accounts for the uncertainties in the process (*e.g.*, accuracy of wildlife populations). The definition is typically denoted by the expression:

TMDL = WLAs + LAs + MOS

The TMDL becomes the amount of a pollutant that can be assimilated by the receiving waterbody and still achieve water quality standards. For these impairments, the TMDLs are expressed in terms of colony forming units (or resulting concentration).

Allocation scenarios were modeled using the HSPF model. Scenarios were created by reducing direct and land-based bacteria until the water quality standards were attained. The TMDLs developed for the impairments in the Little River watershed were based on the *E. coli* riverine Virginia State standards. As detailed in Section 2.1, the VADEQ riverine primary contact recreational use *E. coli* standard states that the calendar month geometric-mean concentration shall not exceed 126 cfu/100 mL.

According to the guidelines put forth by the VADEQ (VADEQ, 2003a) for modeling bacteria with HSPF, the model was set up to estimate loads of fecal coliform, then the model output was converted to concentrations of *E. coli* through the use of the following equation (developed from a data set containing 493 paired data points):

$$\log_2(C_{ec}) = -0.0172 + 0.91905 \cdot \log_2(C_{fc}) \qquad \textit{E. coli}$$

where C_{ec} is the concentration of *E. coli* in cfu/100 mL and C_{fc} is the concentration of fecal coliform in cfu/100 mL.

Pollutant concentrations were modeled over the entire duration of a representative modeling period and pollutant loads were adjusted until the standards were met. The development of the allocation scenario was an iterative process that required numerous runs with each followed by an assessment of source reduction against the applicable water quality standards.

Margin of Safety (MOS)

In order to account for uncertainty in modeled output, a margin of safety (MOS) was incorporated into the TMDL development process. Individual errors in model inputs, such as data used for developing model parameters or data used for calibration, may affect the load allocations in a positive or a negative way. A MOS can be incorporated implicitly in the model through the use of conservative estimates of model parameters, or explicitly as an additional load reduction requirement. The intention of an MOS in the development of a bacteria TMDL is to ensure that the modeled loads do not underestimate the actual loadings that exist in the watershed. An implicit MOS was used in the development of these TMDLs. By adopting an implicit MOS in estimating the loads in the watershed, it is ensured that the recommended reductions will in fact succeed in meeting the water quality standard. Examples of the implicit MOS used in the development of these TMDLs are:

- Allocating permitted point sources at the maximum allowable fecal coliform concentration, and
- Selecting a modeling period that represented the critical hydrologic conditions in the watershed. Such conditions include both high and low flows, both of which are critical in the current study.

Waste Load Allocations (WLAs)

There are four single family homes permitted to discharge into the little River study area. The allocation for the sources permitted for *E. coli* control is equivalent to their current permit levels (design discharge and 126 cfu/100 ml). Future growth in the watershed was accounted for by setting aside 1% of the TMDL for growth in permitted discharges or creation of new ones.

Load Allocations (LAs)

Load allocations to nonpoint sources are divided into land-based loadings from land uses (nonpoint source, NPS) and directly applied loads in the stream (livestock, wildlife, and straight pipes). Source reductions include those that are affected by both high and low flow conditions. Land-based NPS loads most significantly impact bacteria concentrations during high-flow conditions, while direct deposition NPS most significantly impact low flow bacteria concentrations. Appendix C shows tables of the breakdown of the annual fecal coliform per animal per land use for contributing subwatersheds.

Bacterial Total Maximum Daily Loads (TMDLs)

Allocation scenarios were run for the entire watershed. All subwatersheds falling within an impairment were allocated to 0% exceedances of all applicable standards. Table 5.1 represents scenarios developed to determine the TMDLs.

The existing condition, Scenario 1, shows violations of the standard at all impaired subwatershed outlets. Scenario 2 (eliminating illicit residential discharges or straight pipes) showed dramatic improvement. Scenario 3 showed that reducing direct discharge of cattle in streams by 50%, in addition to eliminating straight pipes, had further improvement, while not enough to meet the standard at all impairments. A 73% reduction to livestock direct deposition into streams, in addition to eliminating straight pipes (Scenario4) would benefit water quality and allows the Little River to have a 0% violation rate of the GM swimming use standard.

Table 5.1 Allocation scenarios for reducing current bacteria loads in the Little River.

		VADEQ *E. coli* Standard percent violations (> 126 GM) by subwatershed																	
Scenario	**Action**	**25 (%)**	**26 (%)**	**27 (%)**	**18 (%)**	**19 (%)**	**13 (%)**	**12 (%)**	**11 (%)**	**10 (%)**	**9 (%)**	**8 (%)**	**7 (%)**	**6 (%)**	**5 (%)**	**4 (%)**	**3 (%)**	**2 (%)**	**1 (%)**
Scenario1 (Existing)	None	12.1	95.7	1.5	62.8	5.5	54.5	94.9	75.6	89.7	50.5	11.4	11.7	0.5	0.1	0.0	53.0	75.0	46.7
Scenario2	Eliminate Straight Pipes	0.0	0.9	0.0	1.8	0.0	0.3	9.3	22.8	8.0	2.0	0.0	0.0	0.0	0.0	0.0	0.2	7.7	3.7
Scenario3*	Reduce Livestock Direct Deposition by 50%	0.0	0.0	0.0	0.0	0.0	0.0	0.8	1.9	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Scenario4*	Reduce Livestock Direct Deposition by 73%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

*Scenarios 3 and 4 also include eliminating straight pipes

Scenario 4 is selected as the final allocation scenario

Figures 5.1 though 5.18 show the existing and allocated monthly geometric mean *E. coli* concentrations, respectively, from the Little River impaired subwatershed outlets. The graph show existing conditions in black, with allocated conditions overlaid in blue.

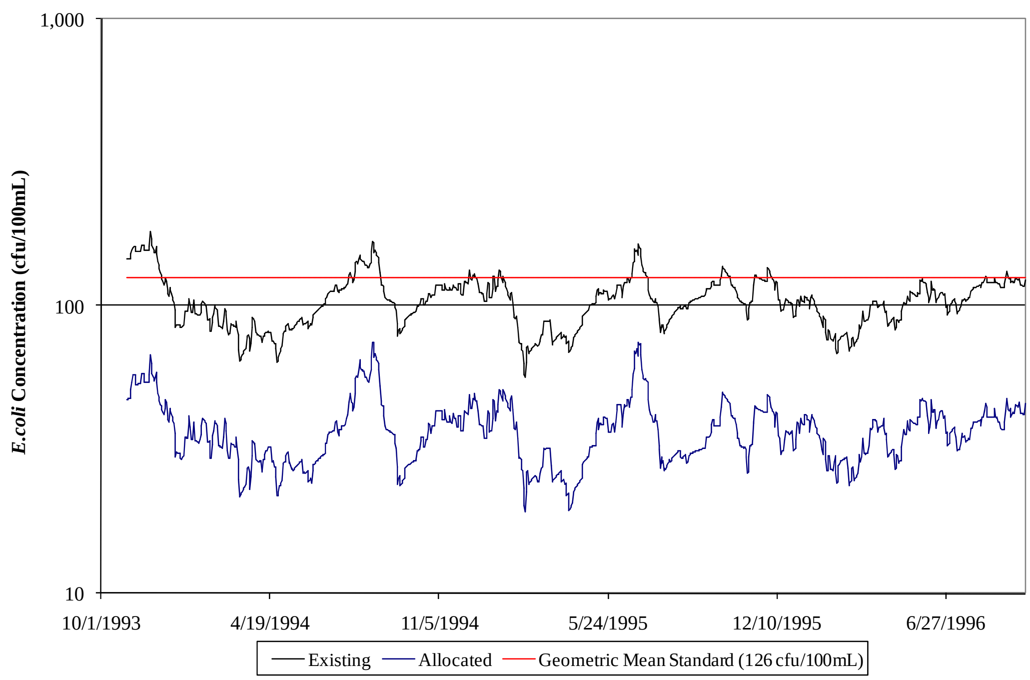

Figure 5.1 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 25.

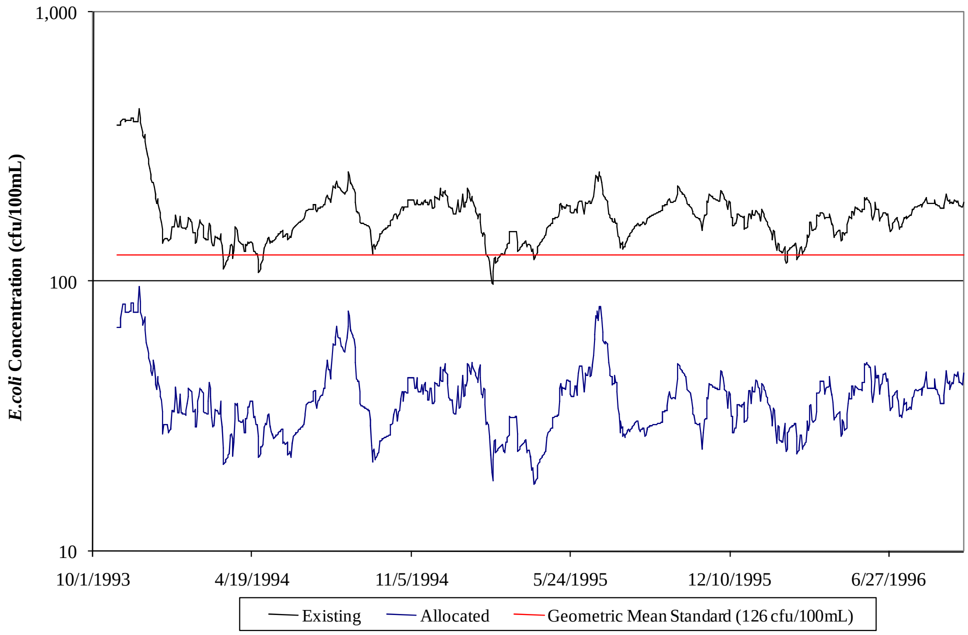

Figure 5.2 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 26.

Figure 5.3 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 27.

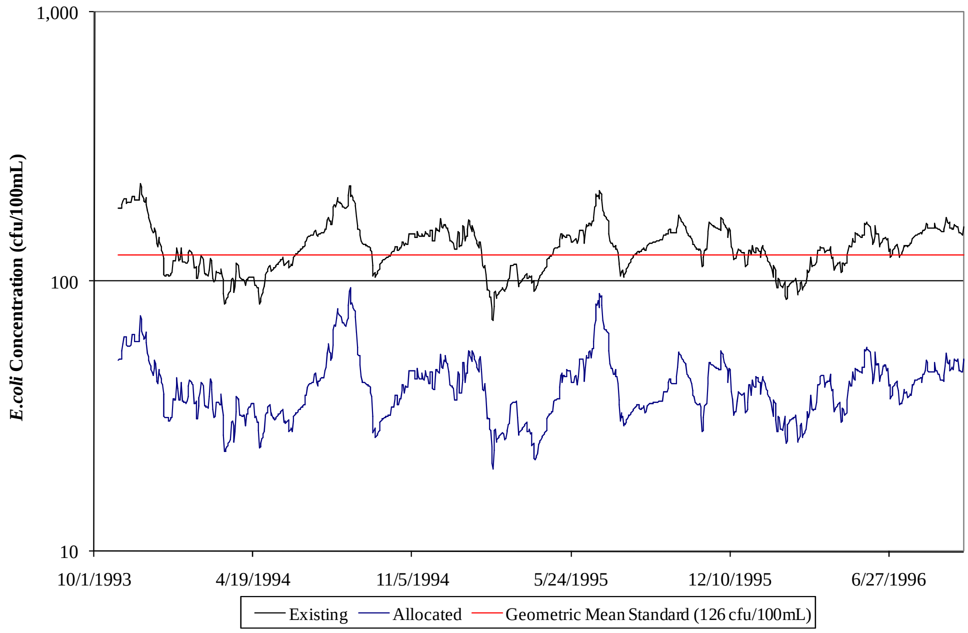

Figure 5.4 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 18.

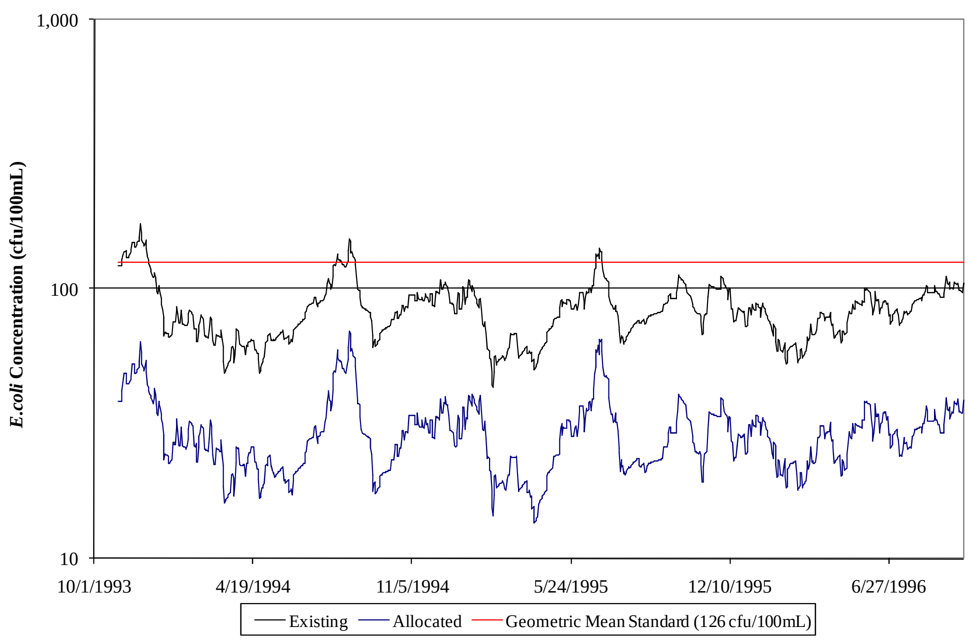

Figure 5.5 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 19.

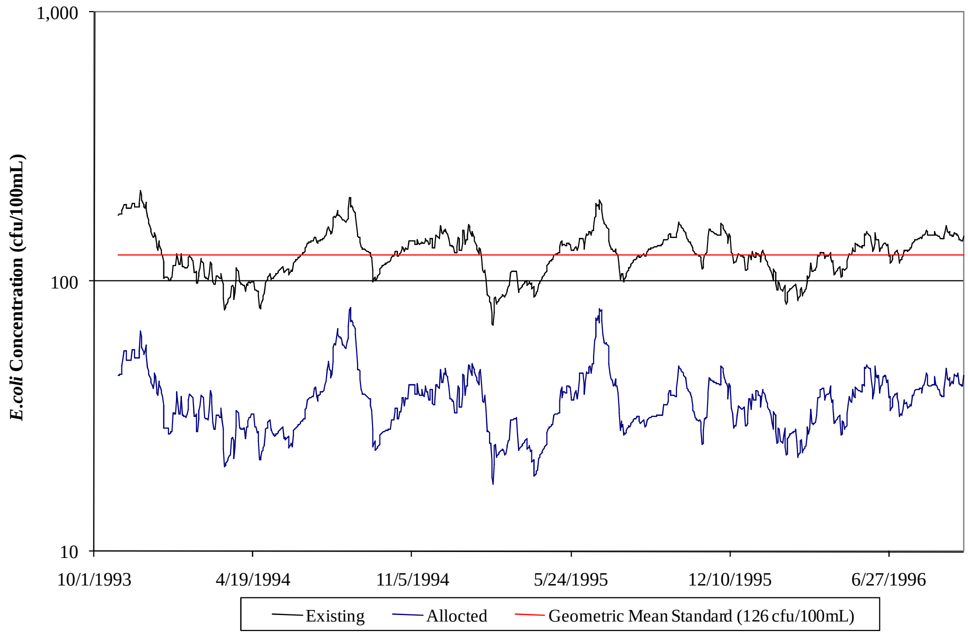

Figure 5.6 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 13.

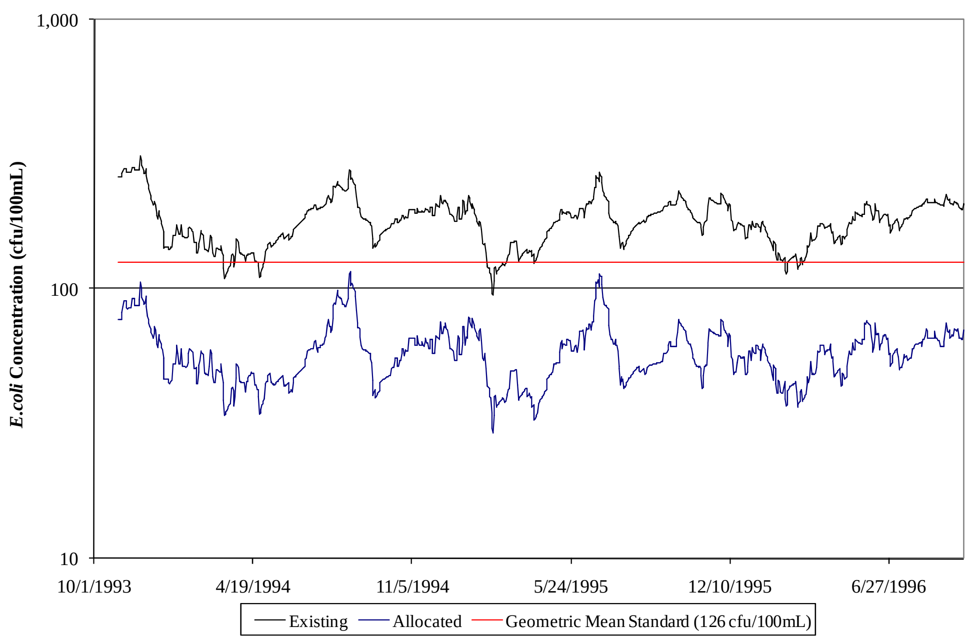

Figure 5.7 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 12.

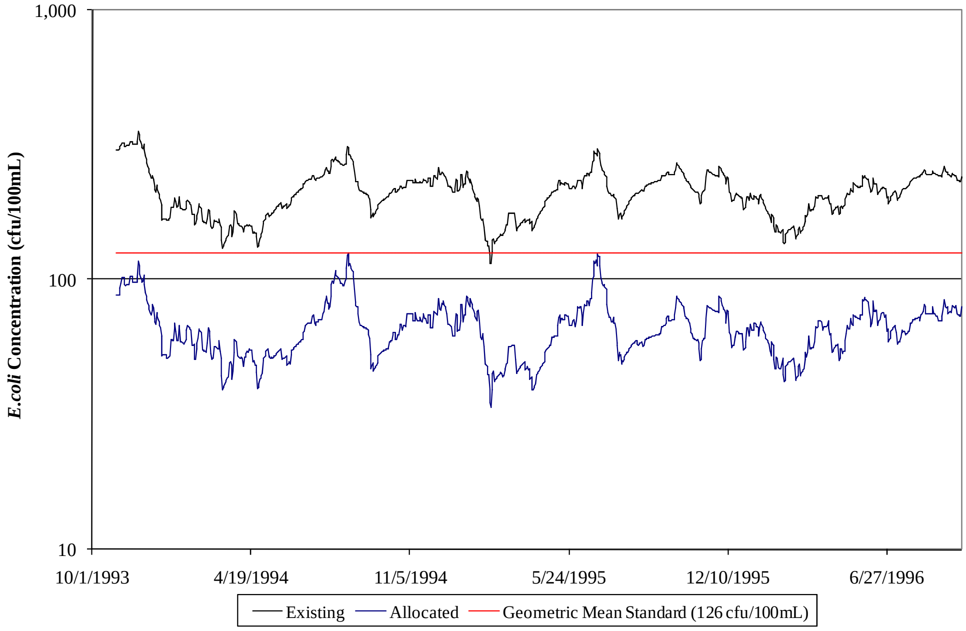

Figure 5.8 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 11.

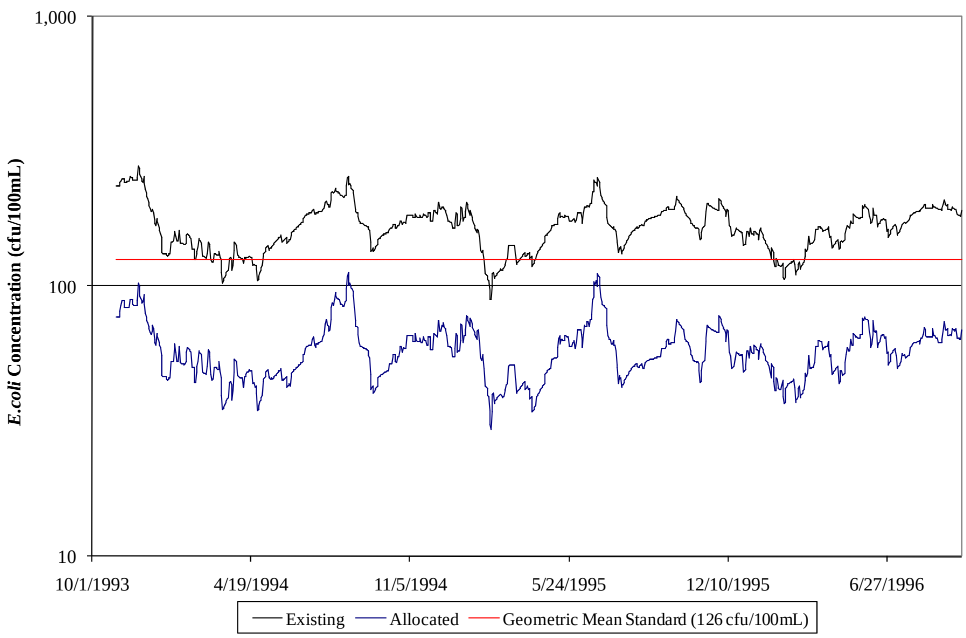

Figure 5.9 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 10.

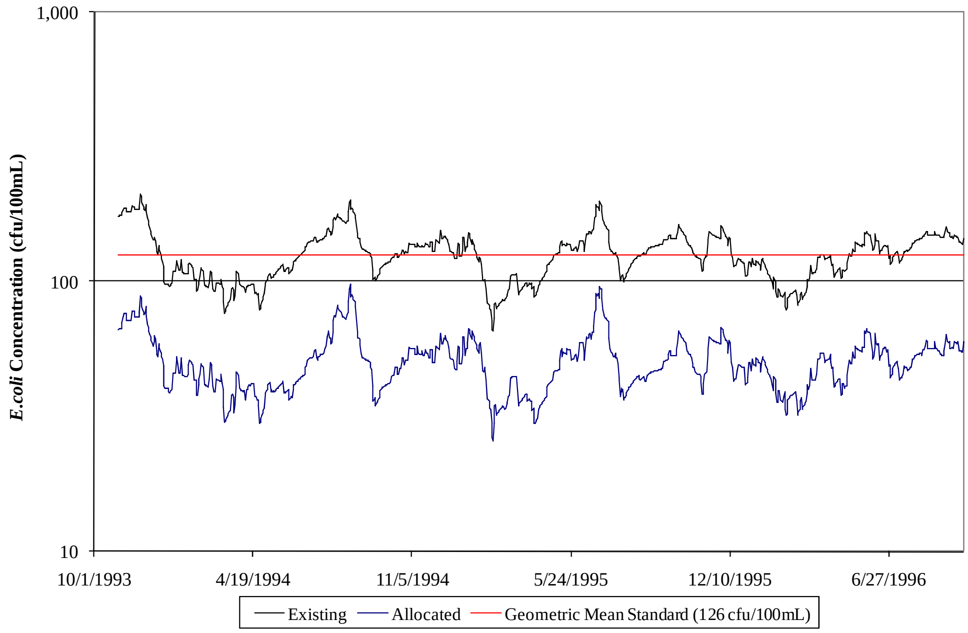

Figure 5.10 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 9.

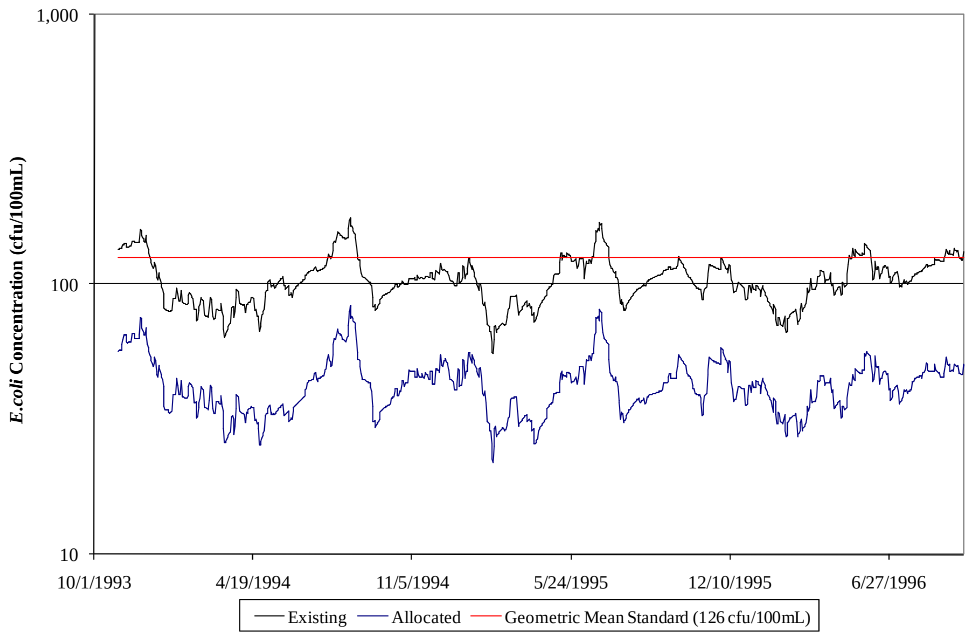

Figure 5.11 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 8.

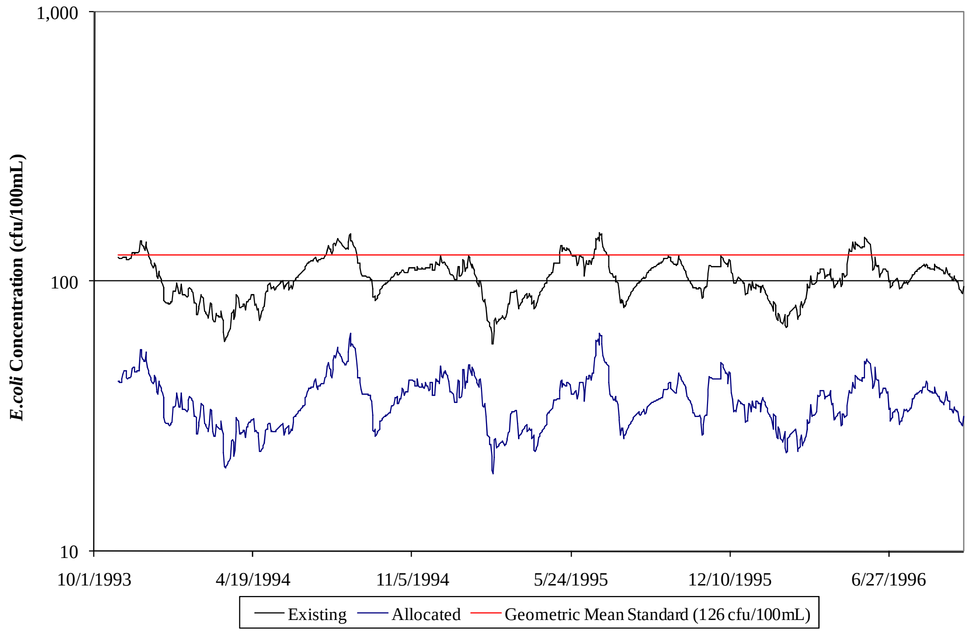

Figure 5.12 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 7.

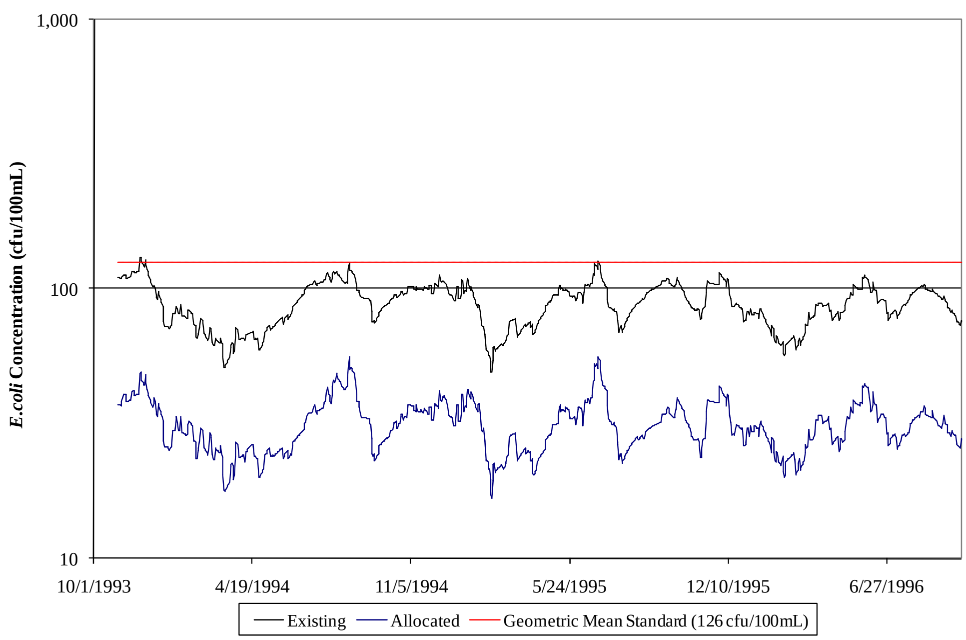

Figure 5.13 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 6.

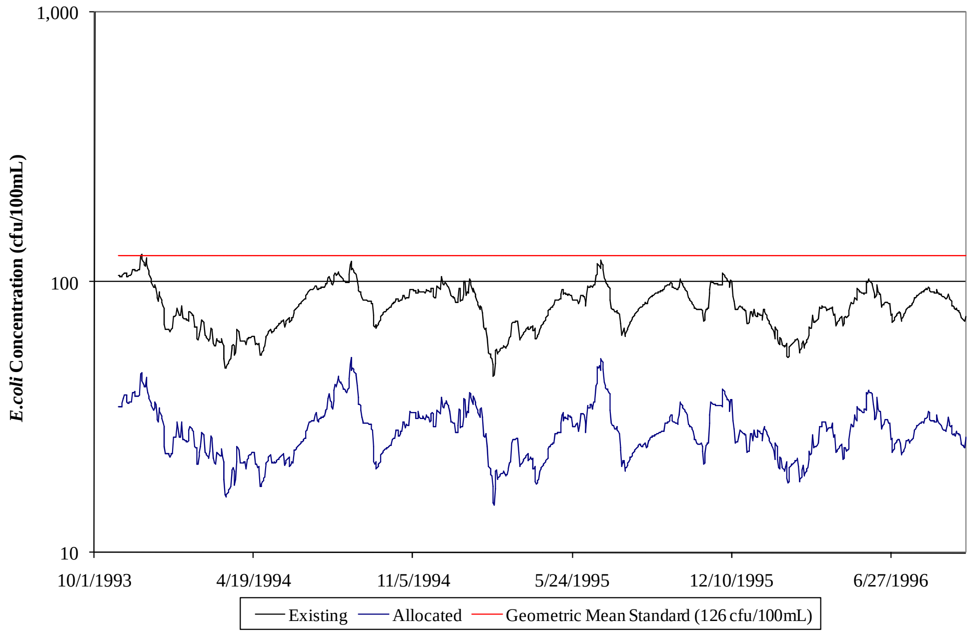

Figure 5.14 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 5.

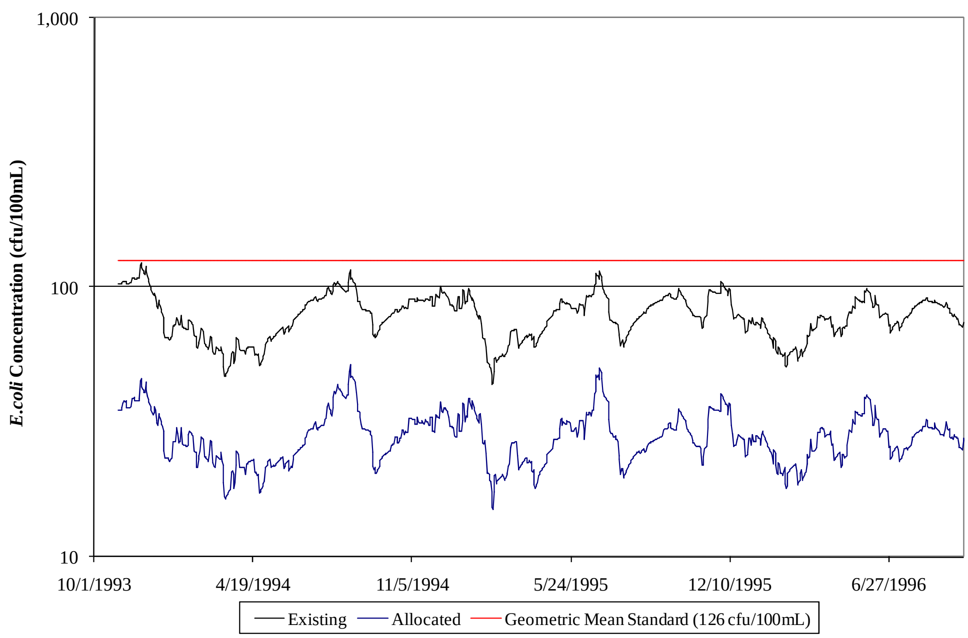

Figure 5.15 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 4.

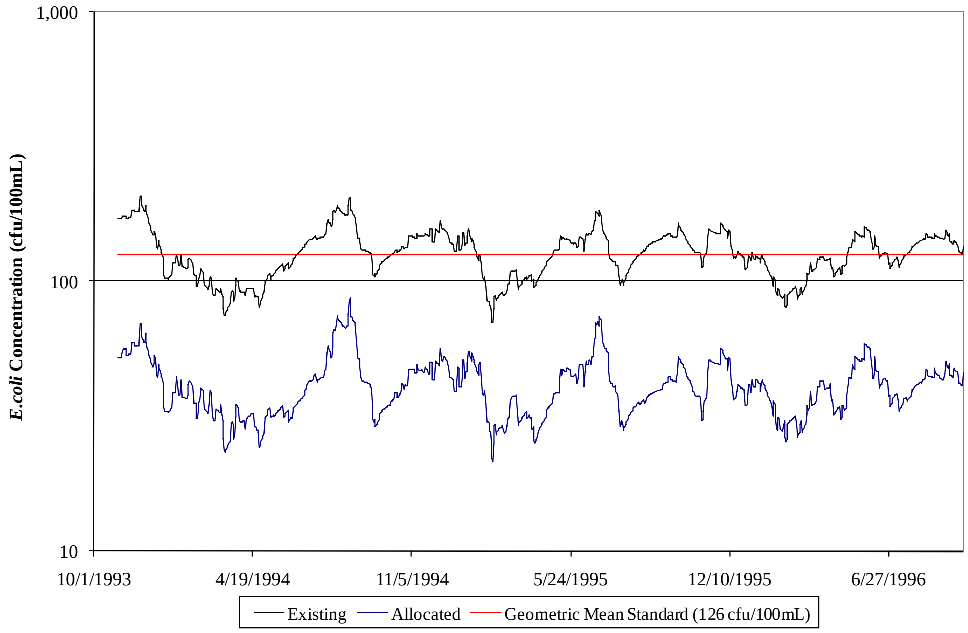

Figure 5.16 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 3.

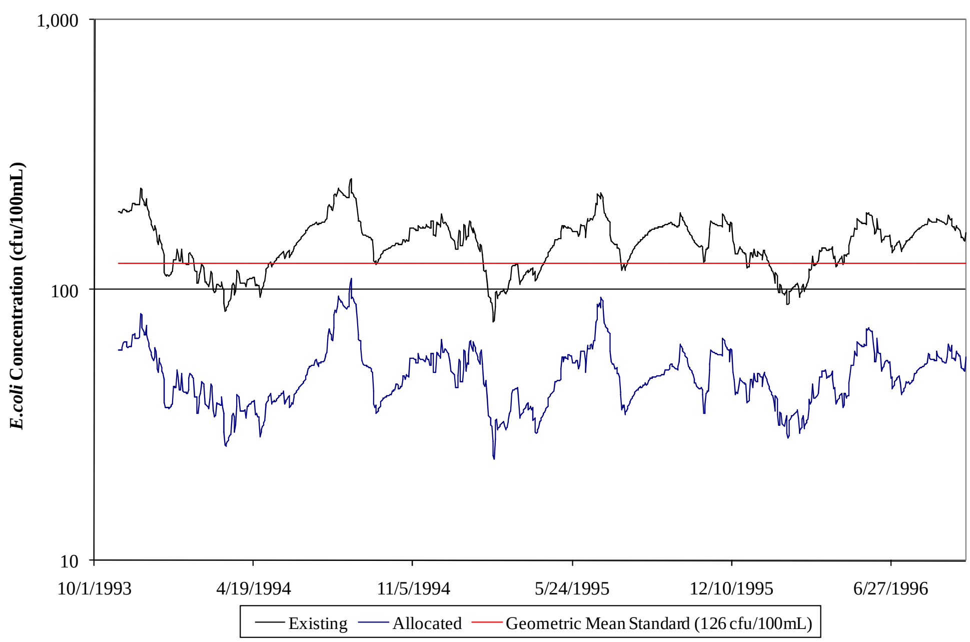

Figure 5.17 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 2.

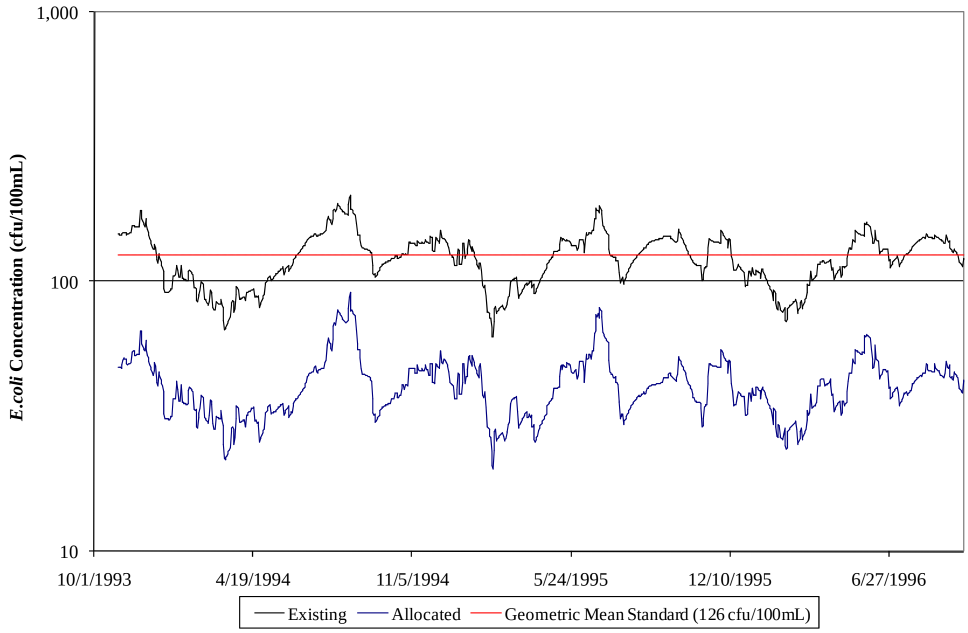

Figure 5.18 Existing and allocated monthly geometric mean in-stream *E. coli* concentrations in subwatershed 1.

Table 5.2 contains estimates of existing and allocated in-stream *E. coli* loads at the Little River impairment outlet reported as average annual cfu per year. The estimates in Table 5.2 are generated from available data, and these values are specific to the impairment outlet for the allocation rainfall for the current land use distribution in the watershed. The percent reductions needed to meet zero percent violations of the 126 cfu/100mL geometric mean standard are given in the final column.

In Appendix C, Tables C.1 through C.4 include the land-based fecal coliform load distributions and offer more details for specific implementation development and source assessment evaluation.

Table 5.2 Estimated existing and allocated *E. coli* in-stream loads in the Little River impairment.

Source	Total Annual Loading for Existing Run (cfu/yr)	Total Annual Loading for Allocation Run (cfu/yr)	Percent Reduction (%)
Land Based			
Barren	8.15E+11	8.15E+11	0%
Developed	2.33E+13	2.33E+13	0%
Commercial	1.26E+12	1.26E+12	0%
Cropland	5.86E+13	5.86E+13	0%
Forest	9.87E+13	9.87E+13	0%
Livestock Access	7.11E+13	7.11E+13	0%
Pasture	7.74E+14	7.74E+14	0%
Wetlands	3.30E+12	3.30E+12	0%
Direct			
Human	1.34E+14	0.00E+00	100%
Livestock	1.50E+14	4.05E+13	73%
Wildlife	4.52E+13	4.52E+13	0%
Permitted Sources	1.13E+13	1.13E+13	0%
Allocated Mill Creek contribution at Little River watershed outlet	3.86E+11	3.86E+11	0%
Allocated Dodd Creek contribution at Little River watershed outlet	3.87E+11	3.87E+11	0%
Total Loads	1.37E+15	1.13E+15	17.5%

Table 5.3 shows the average annual TMDL, which gives the average amount of bacteria that can be present in the stream in a given year, and still meet the water quality standard. These values are output from the HSPF model and incorporate in-stream die-off and other hydrological and environmental processes involved during runoff and stream routing techniques within the HSPF model framework. To account for future growth of urban and residential human populations, one percent of the final TMDL was set aside for future growth in the WLA portion.

Table 5.3 Final average annual in-stream *E. coli* bacterial loads (cfu/year) modeled after TMDL allocation in the Little River impairment.

Impairment	WLA[1]	LA	MOS	TMDL[2]
Little River (watershed outlet)	**1.13E+13**	**1.12E+15**	*Implicit*	**1.13E+15**
VAG402090	*1.74E+09*			
VAG402042	*1.74E+09*			
VAG402051	*1.74E+09*			
VAG402018	*1.74E+09*			
Future Load	*1.13E+13*			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

Starting in 2007, the USEPA has mandated that TMDL studies include a daily load as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach to developing load duration bacterial TMDLs. The daily average in-stream loads for Little River are shown in Table 5.4. The daily TMDL was calculated using the 99th percentile daily flow condition during the allocation time period at the numeric water quality criterion of 235 cfu/100mL. The daily WLA is the annual divided by 365 and the daily LA is the difference between the TMDL and WLA. This calculation of the daily TMDL does not account for varying stream flow conditions.

Table 5.4 Final average daily in-stream *E. coli* bacterial loads (cfu/day) modeled after TMDL allocation in the Little River impairment.

Impairment	WLA[1]	LA	MOS	TMDL[2]
Little River (watershed outlet)	**3.09E+10**	**1.41E+13**	*Implicit*	**1.41E+13**
VAG402090	4.77E+06			
VAG402042	4.77E+06			
VAG402051	4.77E+06			
VAG402018	4.77E+06			
Future Load	3.09E+10			

[1] The WLA reflects an allocation for potential future permits issued for bacteria control. Any issued permit will include bacteria effluent limits in accordance with applicable permit guidance and will ensure that the discharge meets the applicable numeric water quality criteria for bacteria at the end-of-pipe.

[2] The TMDL is presented for the 99th percentile daily flow condition at the numeric water quality criterion of 235 cfu/100ml. The TMDL is variable depending on flow conditions. The numeric water quality criterion will be used to assess progress toward TMDL goals.

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6. BENTHIC MACROINVERTEBRATE COMMUNITY WATER QUALITY ASSESSMENT

6.1 Applicable Criterion for Benthic Macroinvertebrate Community Impairment

The General Standard**,** as defined in Virginia state law 9 VAC 25-260-20, states:

> A. *All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life.*

The General Standard used to be implemented by VADEQ through application of the modified Rapid Bioassessment Protocol II (RBP II) (Barbour, 1999). However, in January 2008, VADEQ moved to a multimetric index approach called the Virginia Stream Condition Index (VASCI) (Burton, 2003). The health of the benthic macroinvertebrate community is assessed through measurement of eight biometrics statistically derived from numerous reference sites in the non-coastal regions of Virginia (Table 6.1). Surveys of the benthic macroinvertebrate community performed by VADEQ are assessed at the family taxonomic level. All eight biometrics in Table 6.1 are measured during all biological monitoring surveys and the total VACSI score is the sum of the eight individual scores. The VADEQ benchmark for a "not impaired" status is a VASCI total score of 60 (if a stream scores less than 60 it is considered impaired).

Table 6.1 Components of the Virginia Stream Condition Index (VASCI).

Biometric	Abbreviation	Benthic Health [1]
Total Taxa Score	Richness Score	↑
EPT Taxa Score	EPT Score	↑
% Ephemeroptera Score	% Ephem. Score	↑
% Plecoptera plus Trichoptera less Hydopschyidae Score	% P+T-H Score	↑
% Scraper Score	% Scraper Score	↑
% Chironomidae Score	% Chironomidae Score	↓
% Two Dominant Families Score	% 2 Dom. Score	↓
Modified Family Biotic Index (MFBI) Score	% MFBI Score	↓

[1] An upward arrow indicates a positive response in benthic macroinvertebrate community health when the associated biometric increases.

6.2 Benthic Macroinvertebrate Community Assessment – Little River

The Little River was initially listed on the *2008 303(d) TMDL Priority List* as not supporting the aquatic life use. All VADEQ water quality monitoring stations related to the biological impairments are shown in Table 6.2 and Figure 6.1.

Table 6.2 VADEQ monitoring stations evaluated for the benthic macroinvertebrate community impairment on the Little River.

Station	Type	Descriptive Location	River Mile
9-LRV032.72	Ambient/Benthic	Rt. 617 Bridge	32.72
9-LRV035.03	Probabilistic	Upstream of Laurel Fork Mouth	35.03
9-LRV044.49	Ambient	Rt. 615 Bridge	44.49

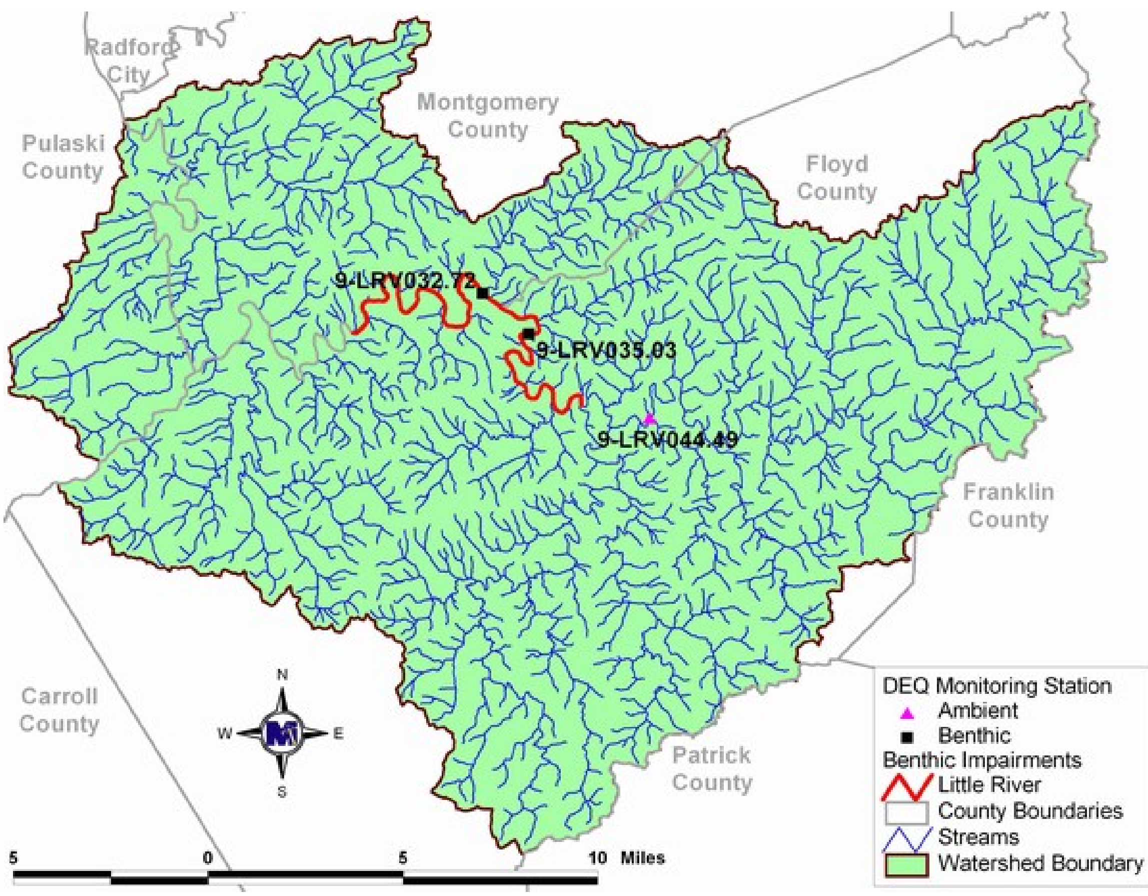

Figure 6.1 VADEQ water quality monitoring stations in the Little River watershed.

Two biological monitoring surveys were performed by the VADEQ in May and September 2004 at probabilistic monitoring station 9-LRV035.03 on the Little River. The VASCI scores are presented in Table 6.3 and Figure 6.2. The results indicate that the spring survey found impaired conditions.

Table 6.3 VASCI biological monitoring scores for station 9-LRV035.03 on the Little River.

Metric	04/07/2004	09/21/2004
Richness Score	72.73	50.00
EPT Score	72.73	45.45
% Ephem. Score	10.61	10.88
% P+T-H Score	9.13	80.01
% Scraper Score	44.12	59.90
% Chironomidae Score	81.30	98.79
% 2 Dom. Score	64.62	62.18
% MFBI Score	70.66	89.57
VASCI Score	**53.24**	**62.10**
Assessment	**Impaired**	**Not Impaired**

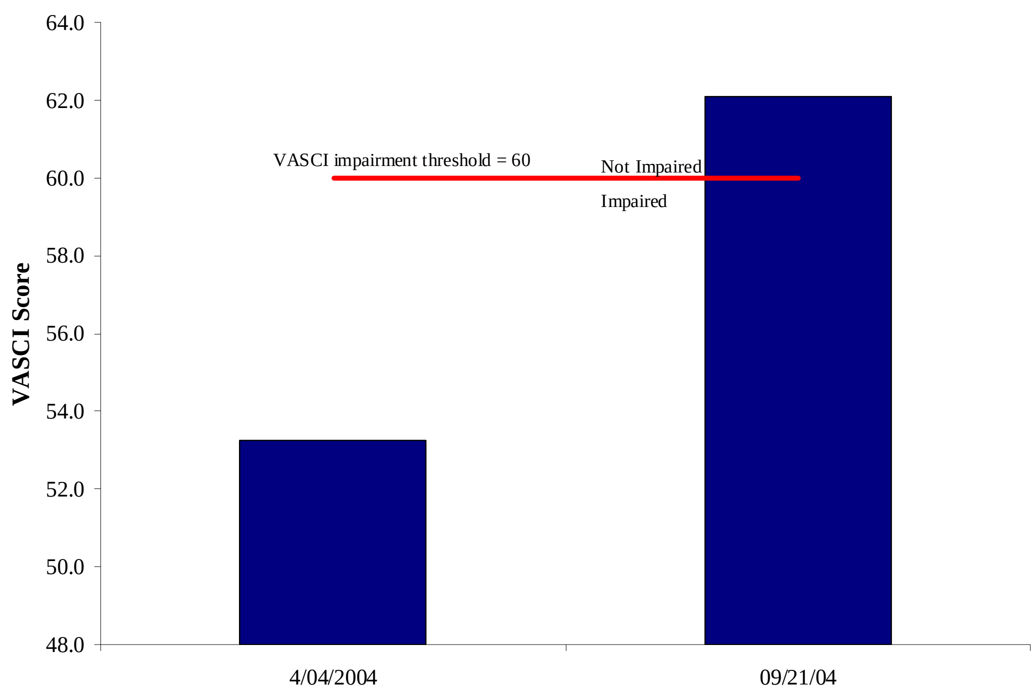

Figure 6.2 VASCI biological monitoring scores for VADEQ probabilistic monitoring station 9-LRV035.03 on the Little River.

One biological monitoring survey was performed at biological monitoring station 9-LRV032.72 on October 19, 2009. The VASCI score is presented in Table 6.4 and Figure 6.3. The result indicates a not impaired condition.

Table 6.4 VASCI biological monitoring scores for station 9-LRV032.72 on the Little River.

Metric	10/19/2009
Richness Score	77.27
EPT Score	100
% Ephem. Score	23.30
% P+T-H Score	16.52
% Scraper Score	79.80
% Chironomidae Score	90.76
% 2 Dom. Score	55.86
% MFBI Score	79.96
VASCI Score	**65.43**
Assessment	**Not Impaired**

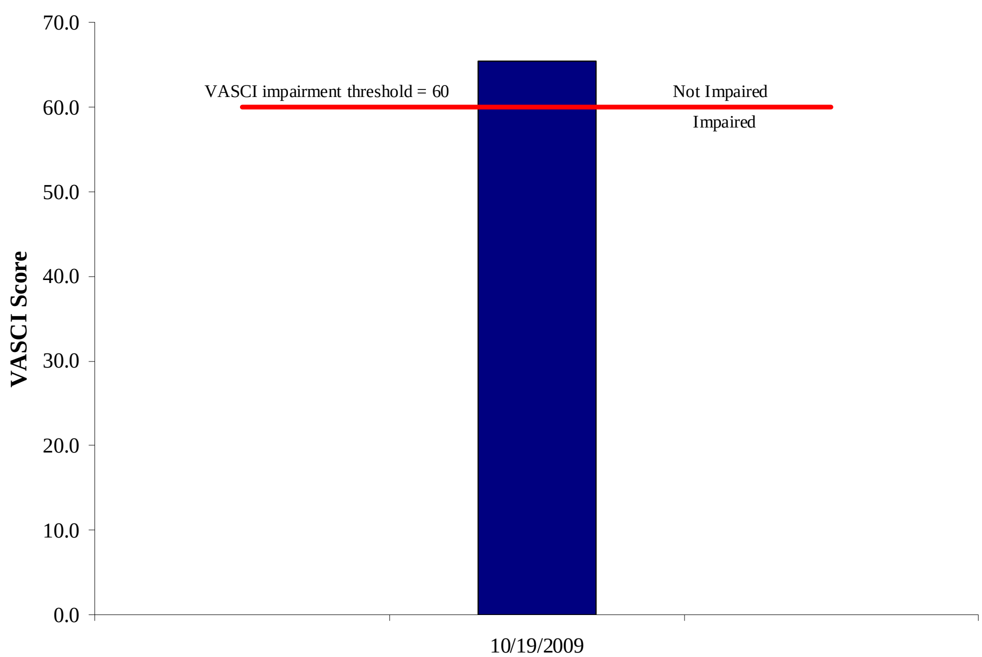

Figure 6.3 VASCI biological monitoring score for VADEQ biological monitoring station 9-LRV032.72 on the Little River.

6.3 Benthic Macroinvertebrate Community Assessment – Meadow Run

Meadow Run was initially listed on the *2008 303(d) TMDL Priority List* as not supporting the aquatic life use. All water quality monitoring stations on Meadow Run are shown in Table 6.5 and Figure 6.4.

Table 6.5 VADEQ monitoring stations on Meadow Run.

Station	Station Type	Descriptive Location	River Mile
9-MDR000.34	Ambient	Rt 641 Bridge	0.34
9-MDR003.60	Probabilistic	Off of Rt. 610	3.60

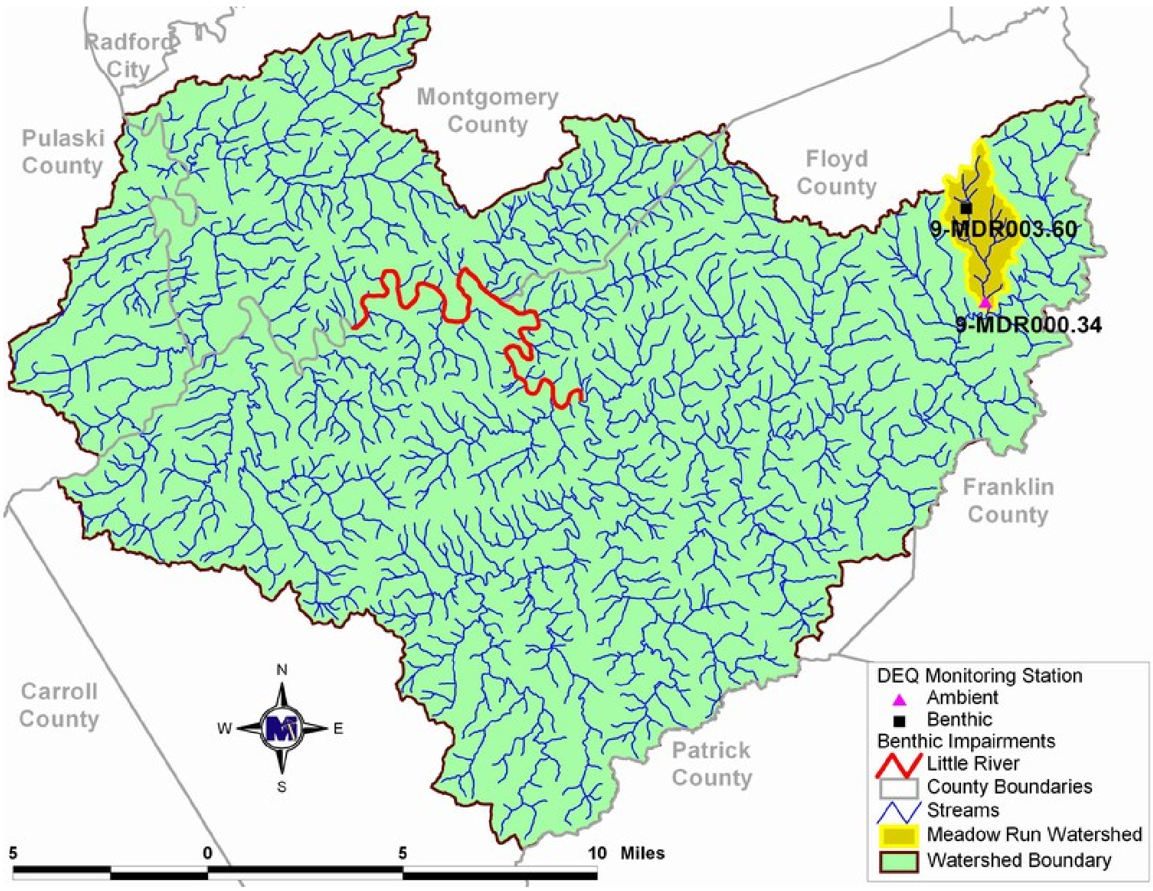

Figure 6.4 Ambient and probabilistic water quality monitoring stations on Meadow Run.

Two biological monitoring surveys were performed by the VADEQ in April and November 2001 at probabilistic monitoring station 9-MDR003.60 on Meadow Run. The VASCI scores are presented in Table 6.6 and Figure 6.5. The results indicate that the surveys found an impaired condition in the spring.

Table 6.6 VASCI biological monitoring scores for station 9-MDR003.60 on Meadow Run.

Metric	04/18/2001	11/01/2001
Richness Score	45.45	59.09
EPT Score	27.27	63.64
% Ephem. Score	21.17	61.69
% P+T-H Score	0.00	11.80
% Scraper Score	19.23	68.40
% Chironomidae Score	38.17	82.35
% 2 Dom. Score	31.99	63.15
% MFBI Score	64.44	75.01
VASCI Score	**30.97**	**60.64**
Assessment	**Impaired**	**Not Impaired**

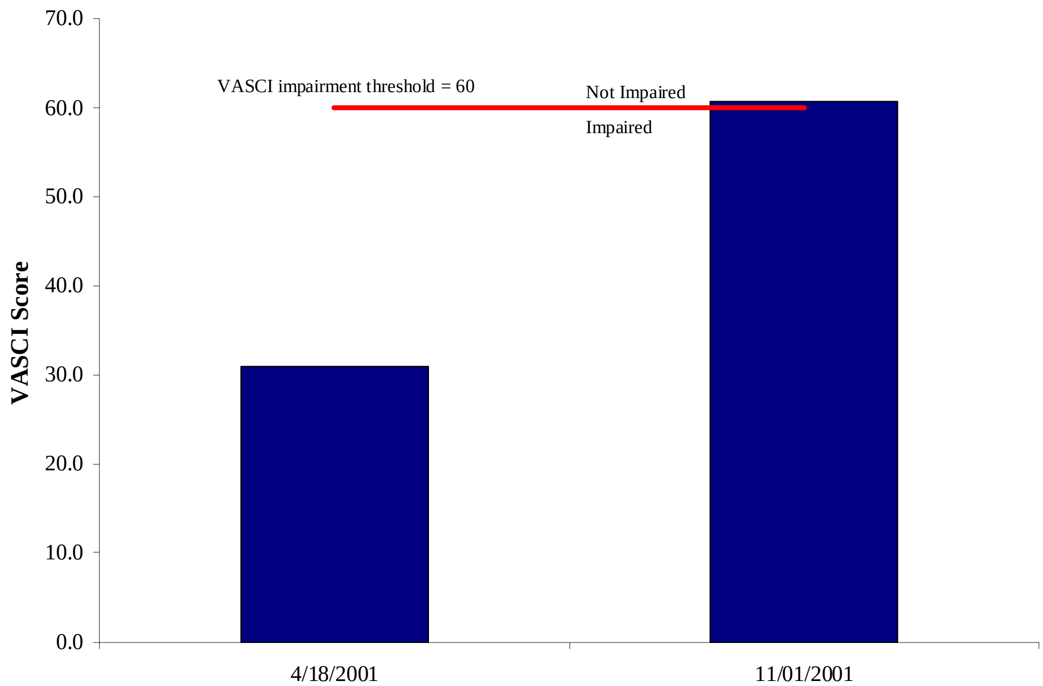

Figure 6.5 VASCI biological monitoring scores for VADEQ probabilistic monitoring station 9-MDR003.60 on Meadow Run.

6.4 Habitat Assessments

Benthic macroinvertebrate community impairments have two general causes: input of pollutants to streams and alteration of habitat in either the stream or the watershed. Habitat can be altered directly (*e.g.,* by channel modification), indirectly (because of changes in the riparian corridor leading to conditions such as streambank destabilization), or even more indirectly (*e.g.*, due to land use changes in the watershed such as clearing large areas).

Habitat assessments are normally carried out as part of the biological monitoring process. The overall habitat score is the sum of ten individual metrics, each metric ranging from 0 to 20. The classification schemes for both the individual habitat metrics and the overall habitat score for a sampling site are shown in Table 6.7.

Table 6.7 Classification of habitat metrics based on score.

Habitat Metric	Optimal	Sub-optimal	Marginal	Poor
Embeddedness	16 - 20	11 – 15	6 - 10	0 - 5
Epifaunal Substrate	16 - 20	11 – 15	6 - 10	0 - 5
Pool Sediment	16 - 20	11 – 15	6 - 10	0 - 5
Flow	16 - 20	11 – 15	6 - 10	0 - 5
Channel Alteration	16 - 20	11 – 15	6 - 10	0 - 5
Riffles	16 - 20	11 – 15	6 - 10	0 - 5
Velocity	16 - 20	11 – 15	6 - 10	0 - 5
Bank Stability	18 - 20	12 – 16	6 - 10	0 - 4
Bank Vegetation	18 - 20	12 – 16	6 - 10	0 - 4
Riparian Vegetation	18 - 20	12 – 16	6 - 10	0 - 4

6.4.1 Habitat Assessment at Biological Monitoring Stations – Little River

Habitat assessment for the Little River includes an analysis of habitat scores recorded by the VADEQ biologists at the probabilistic and biological monitoring stations. The VADEQ habitat assessments for 9-LRV035.03 are displayed in Table 6.8. The Pool Sediment metric assesses the amount of sediment that collects in pool areas of the stream. The spring 2004 Pool Sediment score at this station was in the marginal category and the fall score was in the poor category, indicating that a significant amount of stream bottom was covered with sediment.

Habitat assessment scores at the VADEQ biological monitoring station 9-LRV032.72 are displayed in Table 6.9. The Pool Sediment score at this station was also in the marginal category.

Table 6.8 Habitat scores for VADEQ monitoring station 9-LRV035.03 on the Little River.

Habitat Metric	04/18/2004	09/21/2004	Average
Embeddedness	12	13	12.5
Epifaunal Substrate	12	7	9.5
Pool Sediment	7	5	6
Flow	20	19	19.5
Channel Alteration	20	17	18.5
Riffles	12	12	12
Velocity	20	16	18
Bank Stability	14	12	13
Bank Vegetation	16	13	14.5
Riparian Vegetation	11	10	10.5
Total	**144**	**124**	**134**

Table 6.9 Habitat scores for VADEQ monitoring station 9-LRV032.72 on the Little River.

Habitat Metric	10/19/2009
Embeddedness	12
Epifaunal Substrate	12
Pool Sediment	8
Flow	18
Channel Alteration	15
Riffles	12
Velocity	16
Bank Stability	14
Bank Vegetation	13
Riparian Vegetation	12
Total	**132**

6.4.2 Habitat Assessment at Biological Monitoring Stations – Meadow Run

Habitat assessment for Meadow Run includes an analysis of habitat scores recorded by the VADEQ biologist at one monitoring station (Table 6.10). Riparian Vegetation is a measure of the width of the natural riparian zone. A healthy riparian zone acts as a buffer for pollutants running off the land, helps prevent erosion, and provides habitat. The Riparian Vegetation around this monitoring station scored in the poor and marginal categories. The Pool Sediment habitat metric scored in the marginal category, indicating that excessive sediment is a problem at this monitoring station.

Table 6.10 Habitat scores at the VADEQ monitoring station on Meadow Run, 9-MDR003.60.

Metric	04/18/2001	11/01/2001	Average
Embeddedness	12	11	11.5
Epifaunal Substrate	12	12	12
Pool Sediment	9	9	9
Flow	17	19	18
Channel Alteration	15	18	16.5
Riffles	14	19	16.5
Velocity	14	10	12
Bank Stability	16	18	17
Bank Vegetation	15	15	15
Riparian Vegetation	5	8	6.5
Total	**129**	**139**	**134**

6.5 Discussion of In-stream Water Quality

This section provides an inventory of available observed in-stream water quality data in the biologically impaired segments of the Little River watershed. An examination of data from water quality stations used in the Section 305(b) assessment and data collected during TMDL development were analyzed. Sources of data and pertinent results are discussed. VADEQ monitoring stations typically consist of two types, targeted and probabilistic. Probabilistic monitoring is the sampling of randomly selected stations. These monitoring stations are generated by a computer program that randomly chooses monitoring sites on rivers and streams throughout Virginia. Water quality monitoring stations in Virginia are typically located at bridges. These monitoring stations are known as targeted monitoring sites.

Targeted monitoring has utility for monitoring regulatory compliance of pollution sources, identifying impaired waters, and for tracking local pollution events. However, it is not appropriate to extrapolate results from targeted stations to unsampled watersheds over large geographic areas. Data to answer such questions are best obtained from sample locations chosen so that all streams have an equal chance of being sampled. In order to address statewide and regional questions about water quality, the Virginia Department of Environmental of Quality (VDEQ) added probabilistic monitoring networks to its estuarine monitoring program in 2000 and its freshwater monitoring program in 2001. The aim of probabilistic monitoring is to provide accurate statewide and regional assessments of the chemical, physical, and biological conditions of Virginia's freshwater resources.

6.5.1 Inventory of Water Quality Monitoring Data

The primary sources of available water quality information for the Little River watershed are:

- Data collected at three VADEQ ambient monitoring stations, and
- Probabilistic data collected at two VADEQ monitoring stations.

6.5.1.1 VADEQ Water Quality Monitoring – Little River

VADEQ has monitored water quality recently at three stations on the Little River in the vicinity of the biologically impaired segment (Table 6.2). The locations of these stations are shown in Figure 6.1. The conventional data is summarized in Table 6.11 through 6.13.

Table 6.11 In-stream water quality data at VADEQ monitoring station 9-LRV032.72 in the Little River (7/2001 – 5/2003).

Water Quality Constituent	Mean	SD[1]	Max	Min	Median	N[2]
Conductivity, µmhos/cm	70	17	85	39	73	11
DO Probe, mg/L	9.9	2.5	14.0	6.1	10.5	10
Field pH, std units	7.6	0.4	8.4	7.1	7.5	10
Inorganic Suspended Solids, mg/L	5.3	3.6	12.0	3.0	3.5	6
NH_3+NH_4-N Total, mg/L	0.05	0.01	0.05	0.04	0.05	2
NO_2-N Total, mg/L	0.01	0.00	0.01	0.01	0.01	3
NO_3-N Total, mg/L	0.44	0.17	0.74	0.15	0.41	11
Phosphorus-Ortho, mg/L	0.03	0.01	0.05	0.02	0.03	8
Temp, Celsius	10.7	7.7	23.5	-0.5	9.9	11
Total Hardness $CaCO_3$, mg/L	37.5	46.6	176.0	5.5	25.6	11
Total Inorganic Solids, mg/L	48.5	10.1	68.0	32.0	49.0	11
Total Kjeldahl Nitrogen, mg/L	0.26	0.10	0.40	0.10	0.20	11
Total Organic Solids, mg/L	20.3	5.3	26.0	10.0	23.0	11
Total Organic Suspended Solids, mg/L	5.5	3.5	8.0	3.0	5.5	2
Total Phosphorus, mg/L	0.03	0.02	0.06	0.01	0.03	11
Total Solids, mg/L	68.7	9.3	81.0	51.0	68.0	11
Total Suspended Solids, mg/L	6.3	5.5	20.0	3.0	5.0	9
Turbidity Hach, FTU	5.7	4.1	12.5	1.4	3.7	9
Turbidity Lab, NTU	7.0	1.7	8.2	5.8	7.0	2

[1]SD: standard deviation, [2]N: number of sample measurements.

Table 6.12 In-stream water quality data at VADEQ monitoring station 9-LRV035.03 in the Little River (4/204 and 9/2004).

Water Quality Constituent	Mean	SD[1]	Max	Min	Median	N[2]
Hardness Ca, mg/L	22	NA	22	22	NA	1
NO_3-N Total, MG/L	0.48	0.028	0.5	0.46	NA	2
Total Inorganic Solids, mg/L	37	NA	37	37	NA	1
Total Kjeldahl Nitrogen, mg/L	0.1	NA	0.1	0.1	NA	1
Total Organic Solids, mg/L	15	NA	15	15	NA	1
Total Phosphorus, mg/L	0.02	0.014	0.03	0.01	NA	2
Total Solids, mg/L	52	NA	52	52	NA	1
Turbidity Lab, NTU	1.6	NA	1.6	1.6	NA	1

[1]SD: standard deviation, [2]N: number of sample measurements, NA not applicable.

Table 6.13 In-stream water quality data at VADEQ monitoring station 9-LRV044.49 in the Little River (8/2003 - 6/2005).

Water Quality Constituent	Mean	SD[1]	Max	Min	Median	N[2]
Conductivity, μmhos/cm	67	13	87	45	71	11
DO Probe, mg/L	10.2	1.8	13.1	7.1	10.6	11
Field pH, std units	7.6	0.3	8.0	7.0	7.6	12
NH_3+NH_4-N Total, mg/L	0.07	0.02	0.08	0.05	NA	2
NO2 and NO3 N-Total, mg/L	0.63	0.16	0.87	0.44	0.57	12
Temp, Celsius	12.1	7.9	23.3	2.2	11.9	12
Total Nitrogen, mg/L	0.8	0.1	1.0	0.6	0.8	12
Total Phosphorus, mg/L	0.03	0.02	0.07	0.01	0.03	12
Total Suspended Solids, mg/L	11.6	6.1	21.0	3.0	11.0	9
Turbidity Lab, NTU	8.0	5.4	17.0	1.5	6.6	12

[1]SD: standard deviation, [2]N: number of sample measurements, NA not applicable.

6.5.1.2 VADEQ Water Quality Monitoring– Meadow Run

VADEQ has monitored water quality recently at two sites on Meadow Run (Table 6.2). The location of this station is shown in Figure 6.3. The data for these stations is summarized in Tables 6.14 and 6.15.

Table 6.14 In-stream water quality data at VADEQ monitoring station 9-MDR000.34 on Meadow Run (8/2003 – 12/2009).

Water Quality Constituent	Mean	SD[1]	Max	Min	Median	N[2]
Conductivity, µmhos/cm	82	16	101	57	89	11
DO Probe, mg/L	10.6	1.4	12.4	8.7	10.9	11
Field pH, std units	7.2	0.6	7.8	6.3	7.3	12
NH_3+NH_4-N Total, mg/L	0.63	NA	0.63	0.63	NA	1
NO_2 and NO_3 N-Total, mg/L	1.0	0.2	1.3	0.7	1.0	12
Temp, Celsius	10.9	6.7	19.5	1.8	12.5	12
Total Nitrogen, mg/L	1.4	0.8	4.7	0.9	1.2	18
Total Phosphorus, mg/L	0.17	0.60	2.50	0.01	0.02	17
Total Suspended Solids, mg/L	187	572	1,816	3	5	10
Turbidity Lab, NTU	180	605	2,100	2	6	12

[1]SD: standard deviation, [2]N: number of sample measurements, NA not applicable.

Table 6.15 In-stream water quality data at VADEQ monitoring station 9-MDR003.60 on Meadow Run (11/01/2001).

Water Quality Constituent	Mean	SD1	Max	Min	Median	N2
Conductivity, µmhos/cm	76	NA	76	76	NA	1
DO Probe, mg/L	9.8	NA	9.8	9.8	NA	1
Field pH, std units	6.9	NA	6.9	6.9	NA	1
NO_3-N Total, mg/L	1.7	NA	1.7	1.7	NA	1
Phosphorus-Ortho, mg/L	0.03	NA	0.03	0.03	NA	1
Temp, Celsius	8.8	NA	8.8	8.8	NA	1
Total Hardness-$CaCO_{3,}$ mg/L	12.4	NA	12.4	12.4	NA	1
Total Inorganic Solids, mg/L	47.0	NA	47.0	47.0	NA	1
Total Kjeldahl Nitrogen, mg/L	0.2	NA	0.2	0.2	NA	1
Total Oganic Solids, mg/L	18.0	NA	18.0	18.0	NA	1
Total Phosphorus, mg/L	0.03	NA	0.03	0.03	NA	1
Total Organic Carbon, mg/L	49.0	NA	49.0	49.0	NA	1
Total Solids, mg/L	65.0	NA	65.0	65.0	NA	1
Total Suspended Solids, mg/L	3.0	NA	3.0	3.0	NA	1
Turbidity Hach, FTU	3.3	NA	3.3	3.3	NA	1

[1]SD: standard deviation, [2]N: number of sample measurements, NA not applicable.

6.5.1.3 Sediment Monitoring – Little River

VADEQ collected in-stream sediment samples in order to test for metals on April 7, 2004 on 9-LRV035.03. No metals exceeded PEC screening concentrations (Table 6.16).

Table 6.16 Sediment metals at VADEQ monitoring station 9-LRV035.03 on Meadow Run (04/07/2004).

Metal, mg/Kg	Value, mg/Kg	PEC, mg/Kg
Aluminum	19,400	NA
Chromium	45.2	111
Copper	23.4	149
Iron	32,000	NA
Lead	17.8	128
Nickel	18.7	48.6
Zinc	103	459

PEC = Probable Effect Concentration (McDonald, 2000).

6.5.1.4 Sediment Monitoring – Meadow Run

VADEQ collected in-stream sediment samples in order to test for metals on November 1, 2001 on 9-MDR003.60. No metals exceeded PEC screening concentrations (Table 6.17).

Table 6.17 Sediment metals at VADEQ monitoring station 9-MDR003.60 on Meadow Run (11/01/2001).

Metal	Value, mg/Kg	PEC, mg/Kg
Aluminum, mg/Kg	38,100	NA
Chromium, mg/Kg	30.9	111
Copper, mg/Kg	9.8	149
Iron mg/Kg	37,600	NA
Lead, mg/Kg	21.2	128
Mangenese, mg/Kg	641	NA
Nickel, mg/Kg	11.6	48.6
Zinc, mg/Kg	107.0	459

PEC = Probable Effect Concentration (McDonald, 2000).

6.5.1.5 Dissolved Metals Sampling Results – Little River

VADEQ collected water column samples in order to test for dissolved metals on April 7, 2004 on 9-LRV035.03. No metals exceeded a WQS (Table 6.18).

Table 6.18 Dissolved metal concentrations at VADEQ monitoring station 9-LRV035.03 on Little River.

Metal	4/7/2004 (ug/L)	Chronic WQS (ug/L)[1]
Aluminum	11.1	NA
Barium	13.0	NA
Chromium	0.38	194.1
Copper	0.34	3.24
Iron	68.0	NA
Manganese	14.18	NA
Mercury[2]	0.00389	0.77
Nickel	0.24	5.65

[1]WQS = VADEQ water quality standard, WQS are based on formulas dependent on the hardness at the time of sampling; N/A = Not Applicable, there is no chronic water quality standard for this metal.
[2]The mercury WQS is not hardness dependent.

6.5.1.6 Special Pollution Response Investigation – Little River

VADEQ's Roanoke office investigated citizen complaints about excessive algae and brown foam in the middle and downstream sections of the Little River in June 2008. Large expanses of submerged aquatic vegetation (SAV) were observed. In addition, long strands of filamentous algae were also found caught up in the SAV (Figure 6.6). Local citizens noted that they had never seen the flows in the river this low or so much algae.

Figure 6.6 VADEQ photo of algae and SAV in the Little River at Rt. 757, June 26, 2008.

Records from the USGS flow gage on the Little River at Graystown (03170000) indicate the average yearly flow in the river for 2008 was 152 cfs. This is the lowest average annual flow recorded since record keeping began in 1928. The median of average annual flows in the river for the 81-year period of record is 359 cfs.

Dissolved oxygen profiles were taken during the investigation and demonstrated that minimum dissolved oxygen concentrations remained well above the minimum WQS of 4.0 mg/L. However, there was a diurnal swing in concentrations of 8.0 mg/L (6.0 mg/L to 14.4 mg/L) indicating excessive primary productivity.

The investigation expanded to the headwaters of the Little River where investigators found evidence of agricultural land uses impacting the watershed. In fact, the 2008 integrated 305(b)/303(d) report rated the Little River watershed as having a high potential for non-point source (NPS) sediment runoff from agricultural land. The upper reaches of the watershed had a high potential for impacts from nutrients due to agricultural NPS runoff (VADEQ, 2008). There was not as much plant growth in the river in the headwaters areas and VADEQ attributed this to a higher gradient, narrower channel and more shade provided by riparian vegetation. Lower velocity, a wider channel and more open canopy characterize the middle and lower sections of the river, which is more conducive to plant growth (VADEQ, 2009).

7. BENTHIC MACROINVERTEBRATE COMMUNITY TMDL ENDPOINT: STRESSOR IDENTIFICATION – LITTLE RIVER

7.1 Stressor Identification – Little River

The Little River begins in northeastern Floyd County and flows in a westerly direction to its confluence with the New River at the Montgomery/Pulaski counties line. Three fourths of the watershed lies within Floyd County with 17% in Montgomery County and 8% in Pulaski County. There are two segments impaired for the Aquatic Life Use on the mainstem of the Little River. The first (VAW-N21R_LRV07A00) begins at Little River's confluence with the West Fork Little River and continues downstream to the end of the natural trout waters designation at the end of Rt 706 for a total of 3.66 stream miles. The second one (VAW-N21R_LRV06A04), begins near the end of Rt 706 and continues downstream to the Little River/Sidney Creek confluence for a total of 13.33 stream miles.

TMDLs must be developed for a specific pollutant(s). Biological monitoring assessments are very good at determining if a particular stream segment is impaired or not, but they usually do not provide enough information to determine the cause(s) of the impairment when organisms are not classified beyond the family level. The process outlined in the Stressor Identification Guidance Document (EPA, 2000) was used to separately identify the most probable stressor(s) for Little River. A list of candidate causes was developed from published literature and VADEQ staff input. Chemical and physical monitoring data provided evidence to support or eliminate potential stressors. Individual metrics for the biological and habitat evaluation were used to determine if there were links to a specific stressor(s). Land use data as well as a visual assessment of conditions along the stream provided additional information to eliminate or support candidate stressors. The potential stressors are: sediment, toxics, low dissolved oxygen, nutrients, pH, metals, temperature, and organic matter.

The results of the stressor analysis for Little River are divided into three categories:

> **Non-Stressor(s)**: Those stressors with data indicating normal conditions, without water quality standard violations, or without the observable impacts usually

associated with a specific stressor, were eliminated as possible stressors. Non-stressors are listed in Table 7.1.

Possible Stressor(s): Those stressors with data indicating possible links, but inconclusive data, were considered to be possible stressors. Possible stressors are listed in Table 7.2.

Most Probable Stressor(s): The stressor(s) with the most consistent information linking it with the poorer benthic macroinvertebrate community and habitat metrics was considered to be the most probable stressor(s). Probable stressors are listed in Table 7.4.

7.2 Non-Stressors

Table 7.1 Non-Stressors in Little River.

Parameter	Location in Document
Low dissolved oxygen	Section 7.2.1
Toxics (ammonia, pesticides, tPCBs and polycyclic aromatic hydrocarbons (PAHs))	Section 7.2.2
Metals (sediment and dissolved)	Section 7.2.3
Temperature	Section 7.2.4
Field pH	Section 7.2.5
Organic matter	Section 7.2.6

There is always a possibility that conditions in the watershed, available data, and the understanding of the natural processes may change beyond what was discovered in this stressor analysis. If additional monitoring shows that different most probable stressor(s) exist or water quality target(s) are protective of water quality standards (WQS), then the Commonwealth will make use of the option to refine the TMDLs for re-submittal to EPA for approval.

7.2.1 Low Dissolved Oxygen

Dissolved oxygen (DO) concentrations were well above the water quality minimum standard at all three VADEQ monitoring stations (9-LRV032.72, 9-LRV035.03 and 9-LRV044.49; Figures 7.1 and 7.2). Probabilistic monitoring station 9-LRV035.03 only had one value collected on 04/07/2004. Low dissolved oxygen is considered a non-stressor.

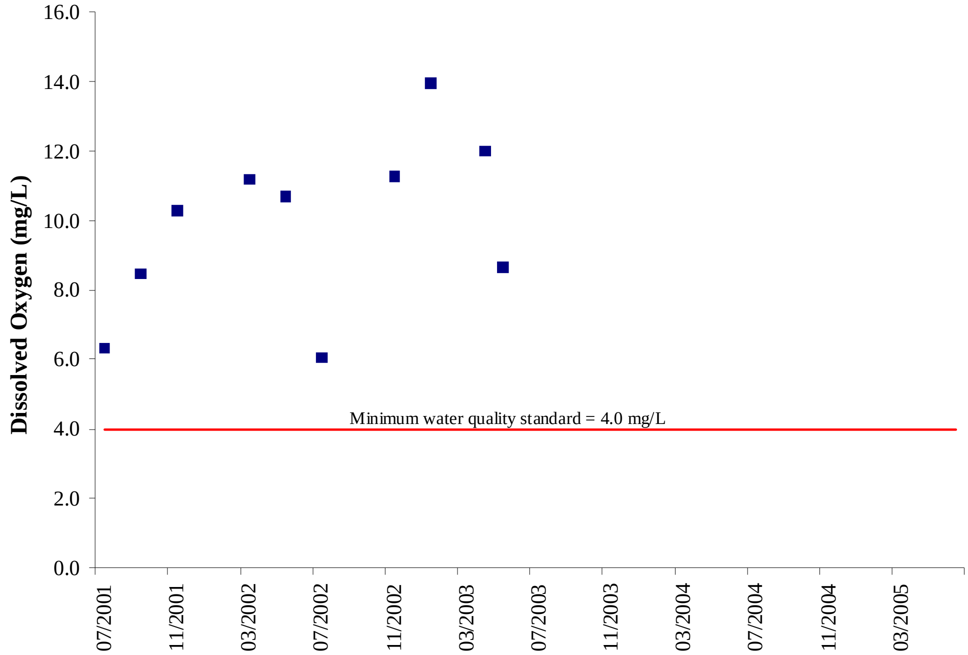

Figure 7.1 Dissolved oxygen concentrations at VADEQ monitoring station 9-LRV032.72.

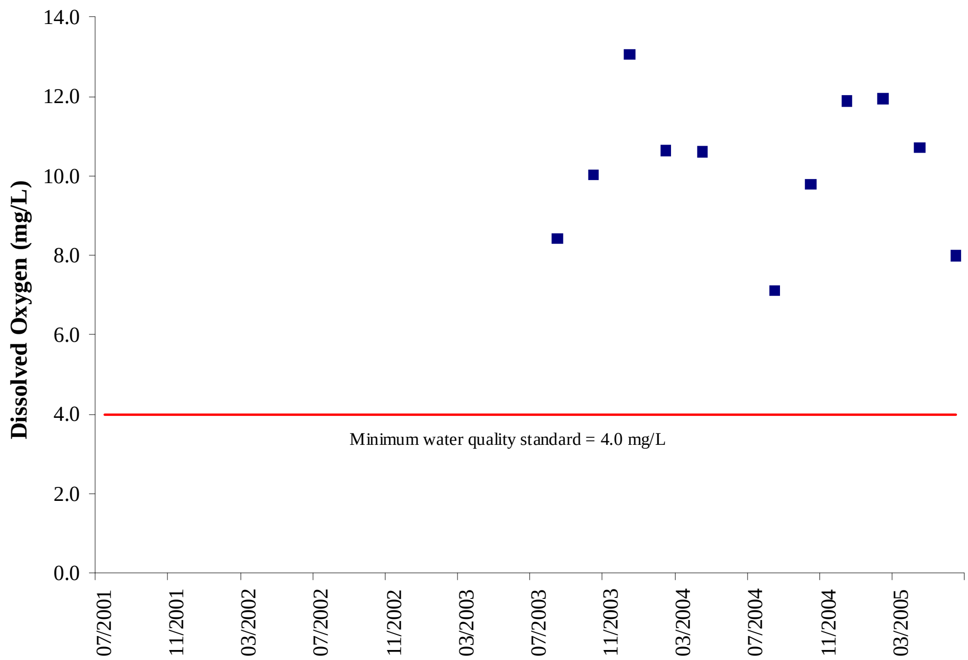

Figure 7.2 Dissolved oxygen concentrations at VADEQ monitoring station 9-LRV044.49.

7.2.2 Toxics (ammonia, tPCBs, Pesticides, and PAHs)

The majority of the ammonia (NH_3/NH_4) samples collected in Little River were below the minimum laboratory level of detection (0.04 mg/L). Only two ammonia (NH_3/NH_4) samples collected at VADEQ monitoring station 9-LRV032.72 and one sample collected at 9-LRV044.49 were above the minimum laboratory detection level; and they were all well below the chronic WQS (chronic and acute ammonia water quality standards vary, depending on the pH and temperature of the stream at the time of sample collection).

Sediment pesticides, PAHs, and tPCBs were all below minimum detection levels at VADEQ probabilistic monitoring station 9-LRV035.03. Ammonia, Pesticides, tPCBs and PAHs are considered non-stressors in the Little River.

7.2.3 Metals

This section discusses VADEQ water quality monitoring for metals dissolved in the water column and metals in the sediment. All in-stream sediment metal values collected at VADEQ probabilistic monitoring station 9-LRV035.03 were below the PEC values. Table 6.14 shows the sediment metals compared to the PEC values.

Water column dissolved metals were sampled at VADEQ probabilistic monitoring station 9-LRV035.03 on the Little River and all results were below the appropriate water quality standard (Table 6.16). Not all of the metals listed have established VADEQ or USEPA water quality standards.

Based on the results of the dissolved and sediment metals data, metals are considered non-stressors.

7.2.4 Temperature

The maximum temperature standard for Little River at the impaired biological monitoring station is 31.0°C. The maximum temperature recorded at VADEQ monitoring station 9-LRV032.72 on the Little River was 23.54°C (Figure 7.3). Probabilistic monitoring station 9-LRV035.03 only had two values collected on 04/07/2004 and 09/21/2004. VADEQ monitoring station 9-LRV044.49 is located just upstream from the impaired segment and it is a section of the Little River that is designated Natural Trout Waters. The maximum temperature standard in Natural Trout Waters is 20^0 C (Figure 7.4). The maximum temperature recorded at this monitoring station was 23.3^0 C. A temperature TMDL was determined for the Little River to account for the natural and stockable trout waters segments (Chapter 12). Therefore, the high temperature values are accounted for in this project.

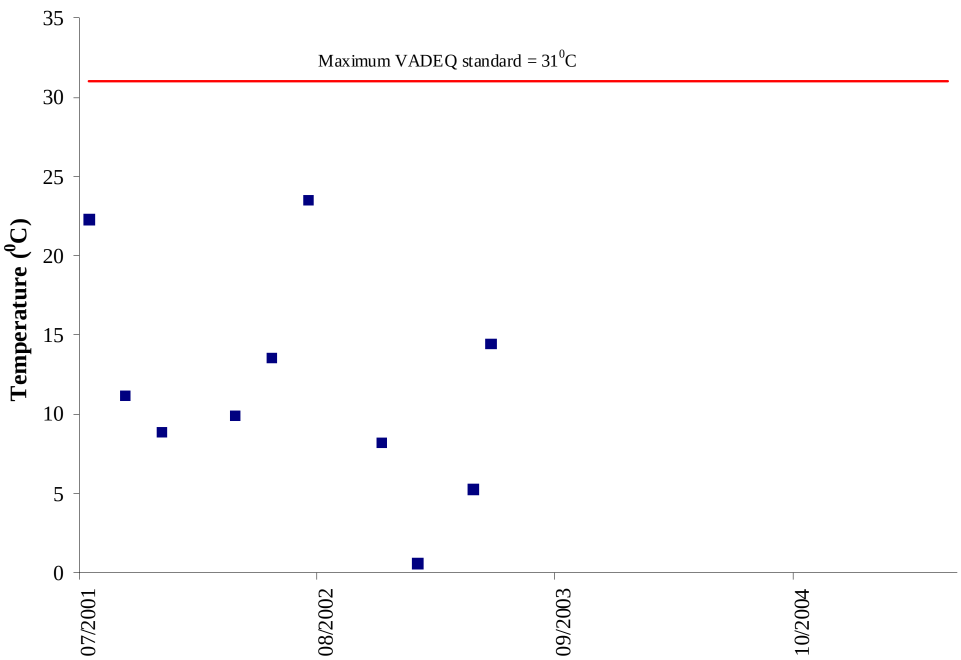

Figure 7.3 Temperature measurements at VADEQ monitoring station 9-LRV032.72.

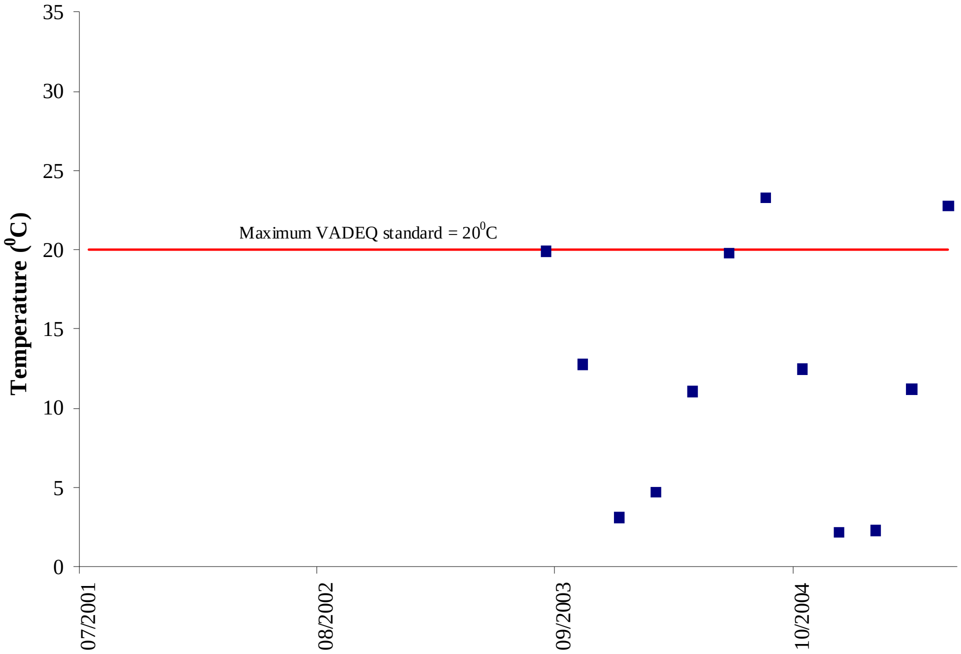

Figure 7.4 Temperature measurements at VADEQ monitoring station 9-LRV044.49.

7.2.5 Field pH

Field pH values were within the minimum and maximum water quality standards at all three VADEQ monitoring stations on the Little River (Figures 7.5 and 7.6). Probabilistic monitoring station 9-LRV035.03 only had two values collected on 04/07/2004 and 09/21/2004. Field pH is considered a non-stressor in the Little River.

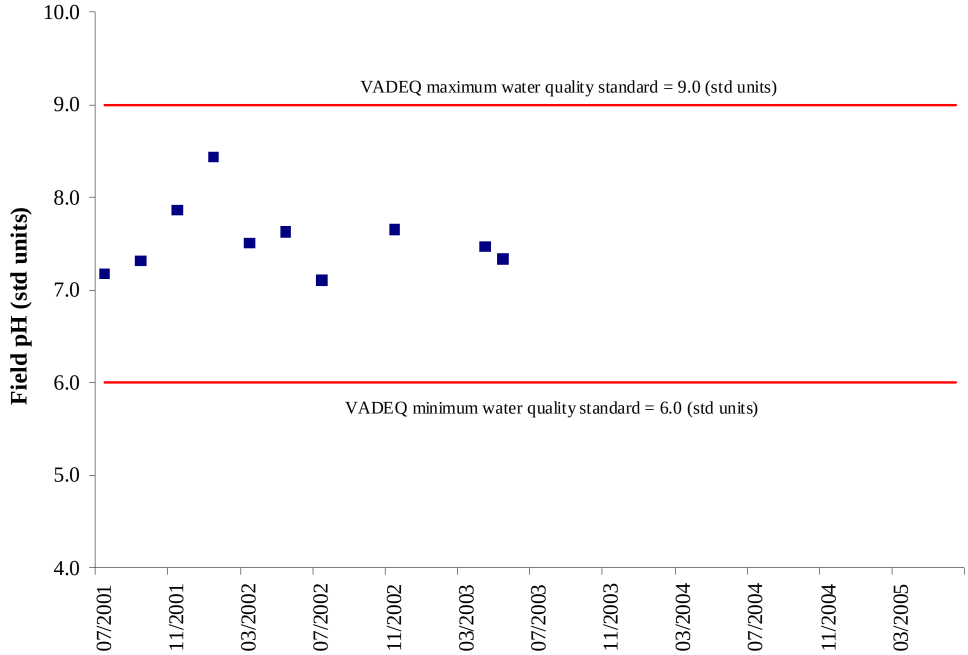

Figure 7.5 Field pH measurements at VADEQ monitoring station 9-LRV032.72.

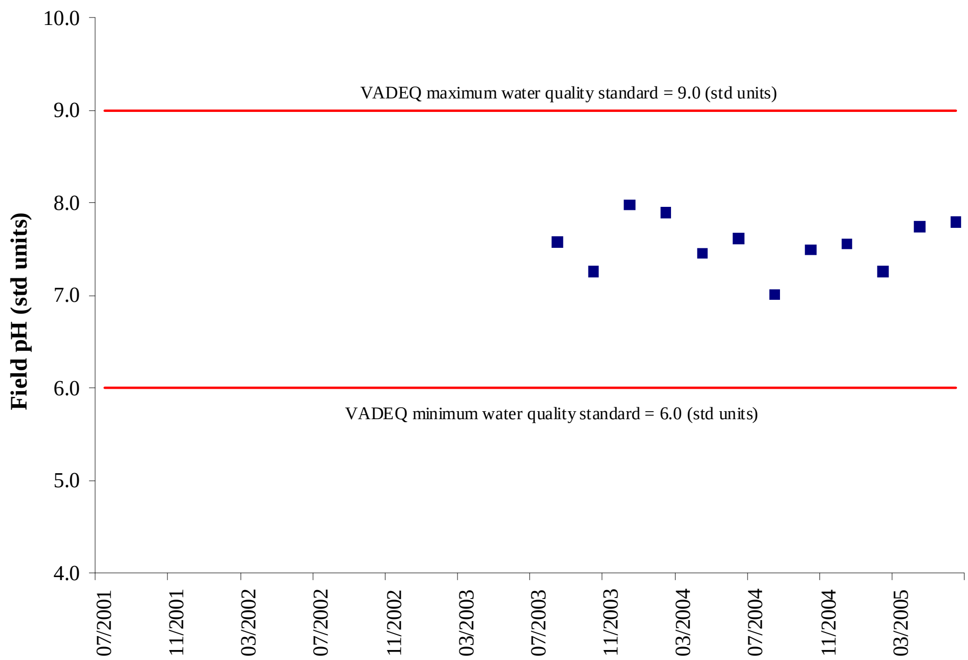

Figure 7.6 Field pH measurements at VADEQ monitoring station 9-LRV044.49.

7.2.6 Organic matter (Total organic solids and total Kjeldahl nitrogen)

Total organic solids (also called total volatile solids, TVS) provide an indication of dissolved and suspended organic matter. Total organic solids concentrations at 9-LRV032.72 were very low, the maximum concentration was only 26 mg/L (Figure 7.7).

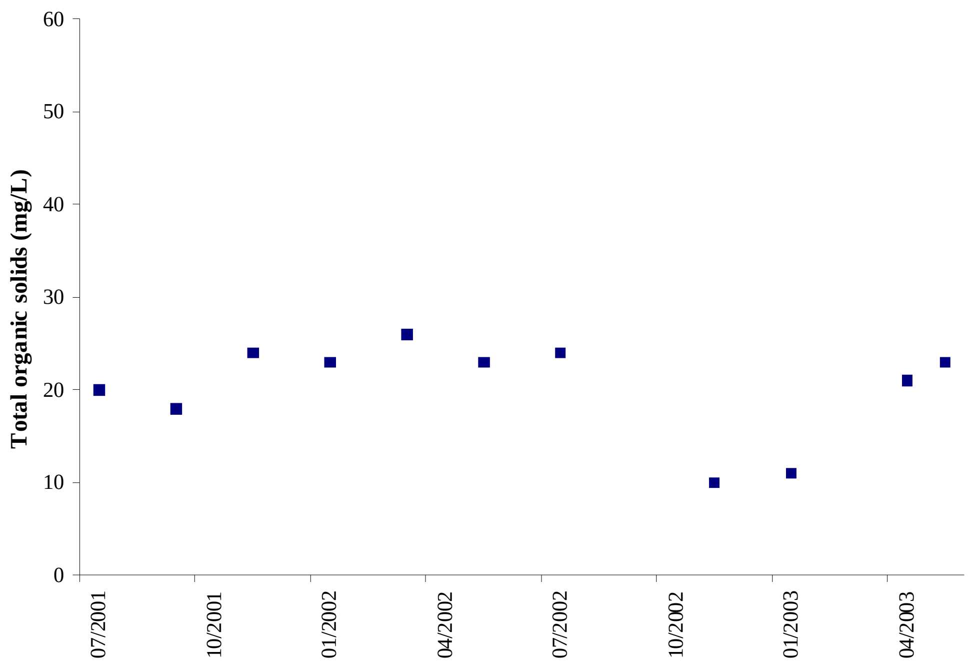

Figure 7.7 Total organic solids concentrations at VADEQ monitoring station 9-LRV032.72.

Total Kjeldahl nitrogen (TKN) is a measure of the amount of organic nitrogen present in the stream. TKN concentrations were very low at VADEQ monitoring station 9-LRV032.72. The maximum concentration found was 0.4 mg/L (Figure 7.8). Organic matter is considered a non-stressor in the Little River.

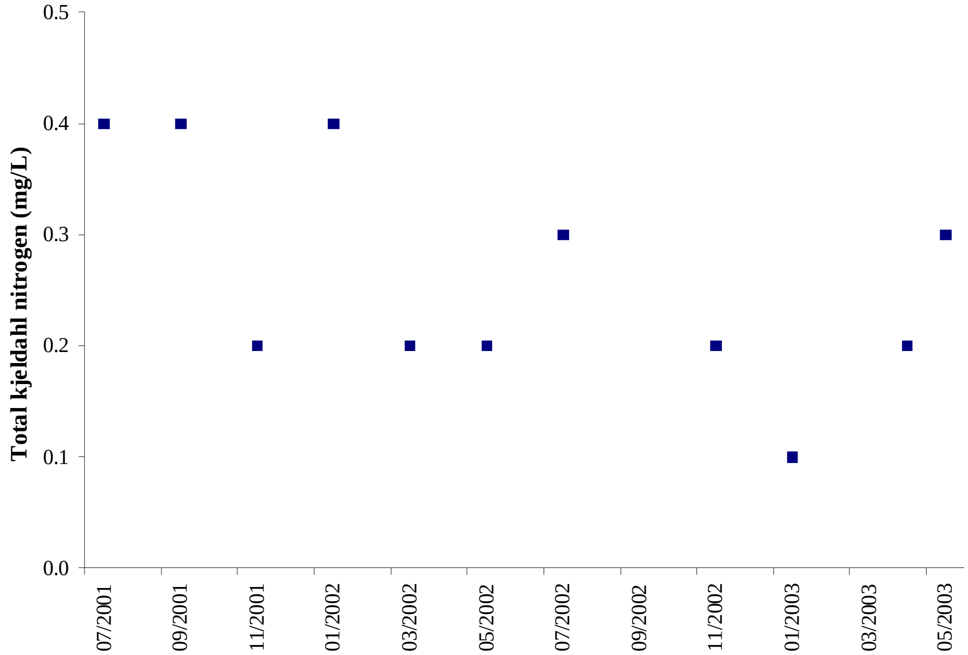

Figure 7.8 Total kjeldahl nitrogen concentrations at VADEQ monitoring station 9-LRV032.72.

7.3 Possible Stressors

Table 7.2 Possible Stressors in the Little River.

Parameter	Location in Document
Nutrients	Section 7.3.1

7.3.1 Nutrients

Total phosphorus (TP) concentrations were generally very low at all three VADEQ ambient monitoring stations. No concentrations exceeded the VADEQ screening value of 0.2 mg/L (Figures 7.7and 7.8). Probabilistic monitoring station 9-LRV035.03 had TP values collected on 04/07/2004 and 09/21/2004. They were 0.01 mg/L and 0.03 mg/L respectively. Nitrate nitrogen concentrations were also low and all values at 9-LRV032.72 were below 0.8 mg/L (Figure 7.9). Probabilistic monitoring station 9-LRV035.03 only had two values collected on 04/07/2004 and 09/21/2004 and the maximum concentration was 0.5 mg/L. A total nitrogen concentration of 0.61 mg/L was found at the probabilistic monitoring station (9-LRV035.03) on 04/07/2004.

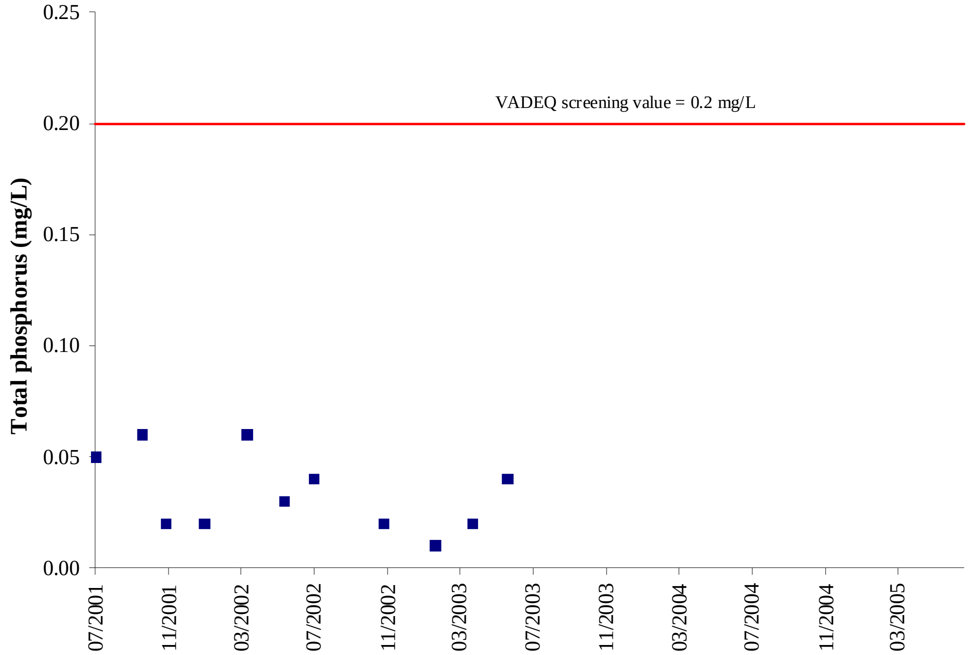

Figure 7.9 Total phosphorus concentrations at VADEQ monitoring station 9-LRV032.72.

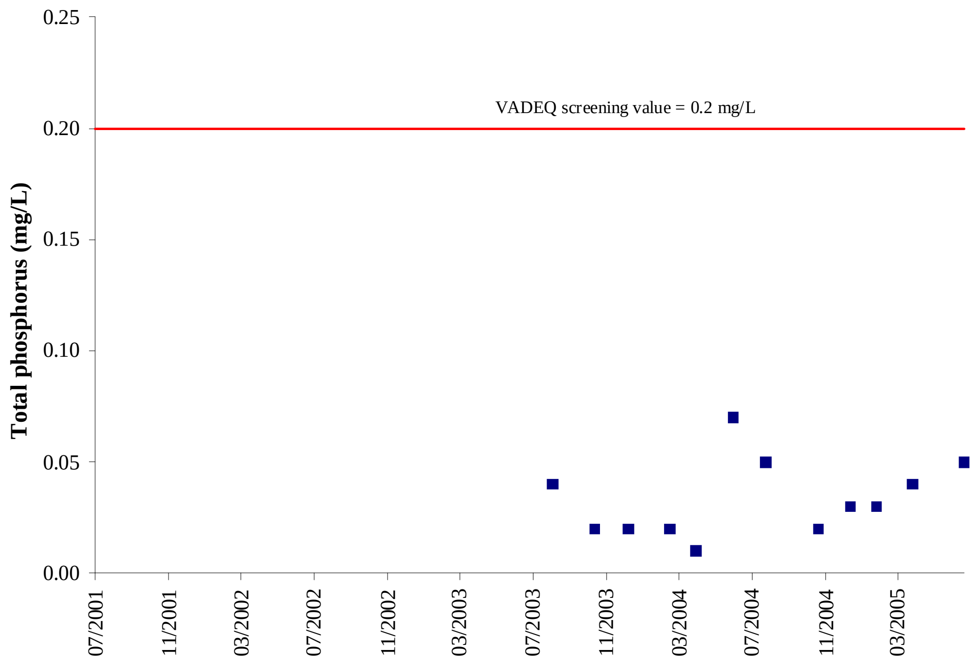

Figure 7.10 Total phosphorus concentrations at VADEQ monitoring station 9-LRV044.49.

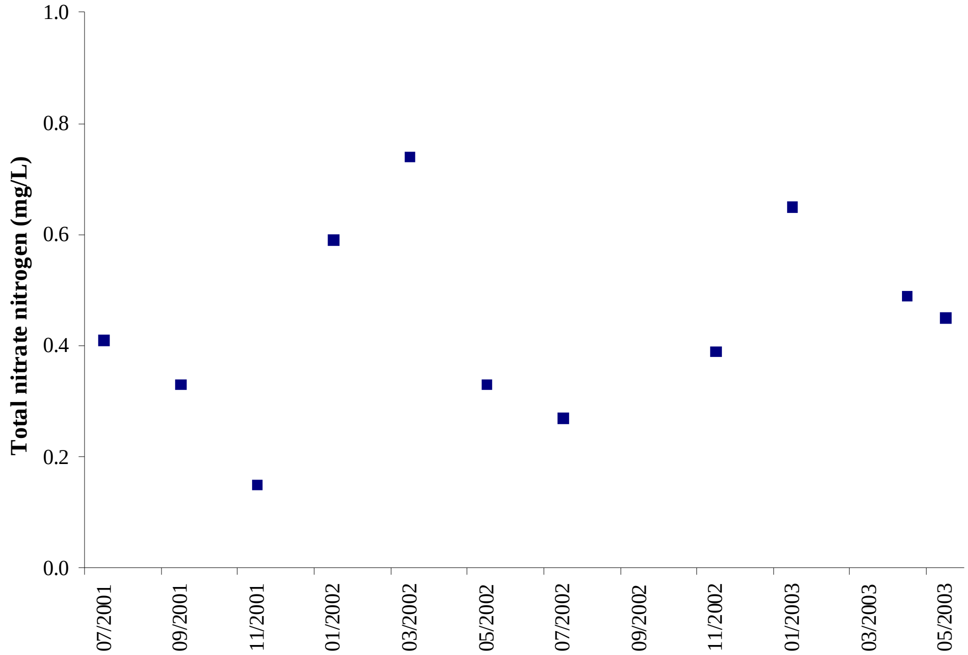

Figure 7.11 Nitrate-nitrogen concentrations at VADEQ monitoring station 9-LRV032.72.

In June 2008 VADEQ received complaints from citizens about excessive algae and plant growth in the middle and lower portions of the Little River. Their investigation is discussed at length in chapter 6 section 6.5.1.6. While the monitored total phosphorus concentrations were very low it is possible that sediment and pore water total phosphorus concentrations are high (pore water is water that fills the spaces between the grains of sediment on the bottom of the stream). Natural and accelerated events that re-suspend sediment in the river could temporarily increase total phosphorus availability and contribute to excessive plant growth under the low flow conditions that existed in 2008. In addition, the non-point source pollution chapter of the 2008 integrated 305(b)/303(d) report rated the headwaters of the Little River as having a high potential for nutrient impacts from agricultural runoff. Based on VADEQ's probabilistic monitoring data total nitrogen concentrations greater than 2.0 mg/L and total phosphorus concentrations greater than 0.05 mg/L can lead to undesirable algae growth and shifts in biological communities (VADEQ 2008). Nutrients are considered possible stressors.

7.4 Most Probable Stressor

Table 7.3 Probable stressors in Little River.

Parameter	Location in Document
Sediment	Section 7.4.1

7.4.1 Sediment

Total suspended solids (TSS) concentrations were relatively low at two VADEQ ambient monitoring stations 9-LRV032.72 and 9-LRV044.49 (Figures 7.12 and 7.13). The highest concentration recorded in the dataset was 21 mg/L in August 2003 at station 9-LRV044.49.

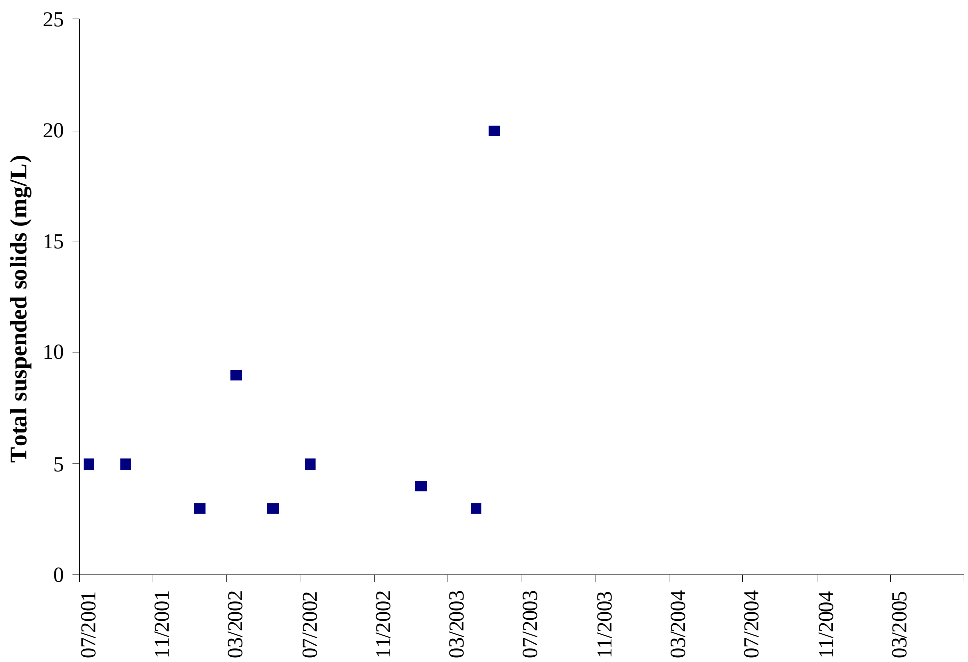

Figure 7.12 TSS concentrations at VADEQ monitoring station 9-LRV032.72.

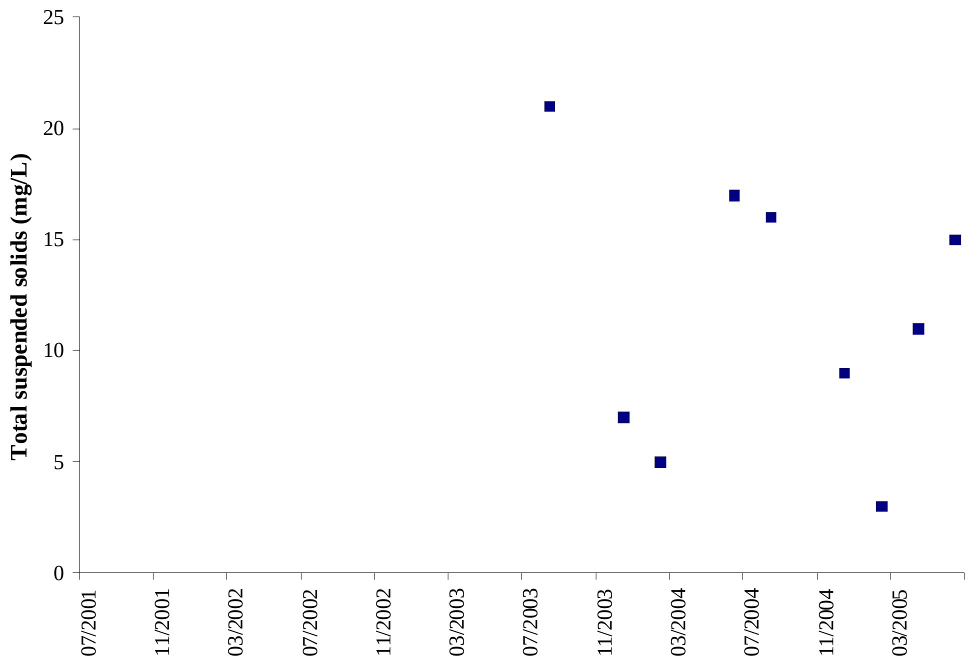

Figure 7.13 TSS concentrations at VADEQ monitoring station 9-LRV044.49.

The habitat data indicates marginal and poor Pool Sediment scores at monitoring station 9-LRV035.03. A poor Pool Sediment score means that the pool is nearly absent due to heavy fine sediment deposition. High levels of sediment deposition are symptoms of an unstable and continually changing environment that becomes unsuitable for many benthic macroinvertebrate organisms.

Part of the probabilistic monitoring protocol requires the use of a Relative Bed Stability (LRBS) index developed by the USEPA. LRBS is the ratio of the observed mean streambed particle diameter to the “critical diameter,” the largest particle size the stream can move as bed load during storm flows. The critical diameter is calculated from field measurements of the size, slope, and other physical characteristics of the stream channel. The index was developed to differentiate between natural and anthropogenic sediment deposition in a watershed. The criterion for a poor condition (an excessive amount of sediment from anthropogenic activities) is –0.9. The index calculation for the Little River at 9-LRV035.03 was –0.81. The USEPA calculates a final LRBS by incorporating the retention pool value, which represents the pool habitat available when streamflow is very low. The LRBS final value calculated by the USEPA on the September 21, 2004 data was -1.363. This is indicates that a significant amount of the sediment deposition in the stream is due to anthropogenic impacts.

The biological monitoring Pool Sediment habitat scores and LRBS index are consistent with the Virginia Department of Conservation and Recreation's high potential for sediment impacts ranking in the Little River watershed found in the 2008 305(b)/303(d) integrated report (VADEQ, 2008). Based on the marginal and poor Pool Sediment habitat scores, an LRBS index score of –0.81 and an LRBS final score of –1.363, sediment is considered a probable stressor in the Little River. Modeling and subsequent TMDL allocations will focus on total sediment delivery (metric tons per year).

8. BENTHIC MACROINVERTEBRATE COMMUNITY TMDL ENDPOINT: STRESSOR IDENTIFICATION – MEADOW RUN

8.1 Stressor Identification – Meadow Run

Meadow Run begins in northeastern portion of Floyd County and flows south to its confluence with the Little River north of Kings Store, Virginia. The impaired segment extends from Meadow Run's headwaters downstream to its confluence with the Little River (3.7 stream miles).

The stressor analysis procedure for Meadow Run was the same as the one used for the Little River, described in Chapter 7 Section 7.1. A list of non-stressors to Meadow Run is found in Table 8.1, possible stressors are shown in Table 8.2 and the most probable stressor in is Table 8.3.

8.2 Non-Stressors

Table 8.1 Non-Stressors in Meadow Run.

Parameter	Location in Document
Low dissolved oxygen	Section 8.2.1
Toxics (ammonia, pesticides, tPCBs and polycyclic aromatic hydrocarbons (PAHs))	Section 8.2.2
Metals (sediment)	Section 8.2.3
Temperature	Section 8.2.4
Field pH	Section 8.2.5

There is always a possibility that conditions in the watershed, available data, and the understanding of the natural processes may change beyond what was revealed in this stressor analysis. If additional monitoring shows that different most probable stressor(s) exist or water quality target(s) are protective of water quality standards, then the Commonwealth will make use of the option to refine the TMDLs for re-submittal to EPA for approval.

8.2.1 Low Dissolved Oxygen

Dissolved oxygen (DO) concentrations were well above the minimum water quality standard at VADEQ monitoring station 9-MDR000.34 (Figure 8.1). Low dissolved oxygen is considered a non-stressor.

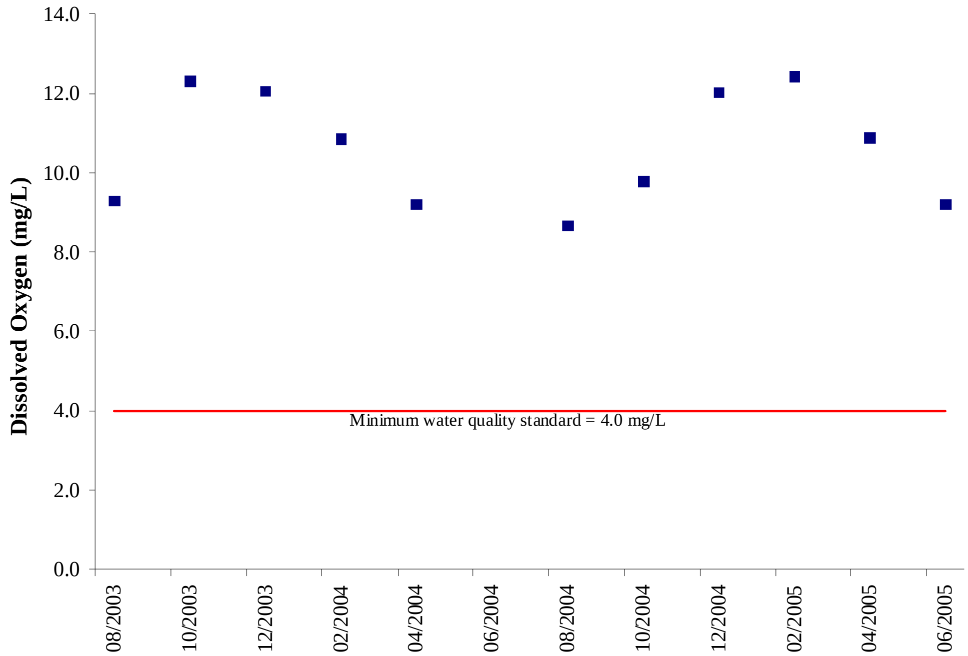

Figure 8.1 Dissolved oxygen concentrations at VADEQ monitoring station 9-MDR000.34.

8.2.2 Toxics (ammonia, Pesticides, tPCBs and PAHs)

All but one of the ammonia (NH_3/NH_4) samples collected in Meadow Run were below the minimum laboratory level of detection (0.04 mg/L), and it was well below the chronic WQS (chronic and acute ammonia water quality standards vary depending on the pH and temperature of the stream at the time of sample collection).

Sediment organics (PAHs), tPCBs and pesticides were collected at VADEQ probabilistic station 9-MDR000.34 November 1, 2001. All sediment PAH and pesticide concentrations in Meadow Run were below the minimum laboratory detection level. Ammonia, pesticides and PAHs are considered non-stressors in Meadow Run.

8.2.3 Metals

This section discusses VADEQ water quality monitoring for sediment metals data collected on November 1, 2001 at VADEQ probabilistic monitoring station 9-MDR003.60. Sediment metal values were below the PEC values (Table 6.16).

Based on the results of the sediment metals data, metals are considered non-stressors in Meadow Run.

8.2.4 Temperature

The maximum temperature WQS for Meadow Run is 20.0°C (natural trout waters standard). The maximum temperature recorded at VADEQ monitoring station 9-MDR000.34 on Meadow Run was 19.5°C (Figure 8.2). Temperature is considered a non-stressor in Meadow Run.

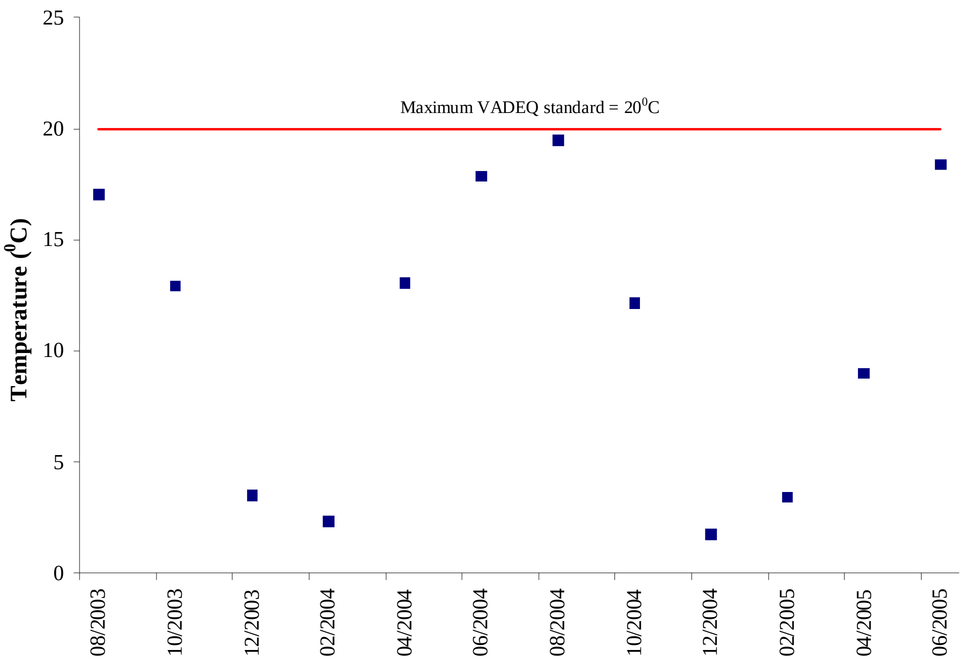

Figure 8.2 Temperature measurements at VADEQ station 9-MDR000.34.

8.2.5 Field pH

Field pH values were within the minimum and maximum water quality standards at VADEQ monitoring station 9-MDR000.34 (Figure 8.3). Field pH is considered a non-stressor in Meadow Run.

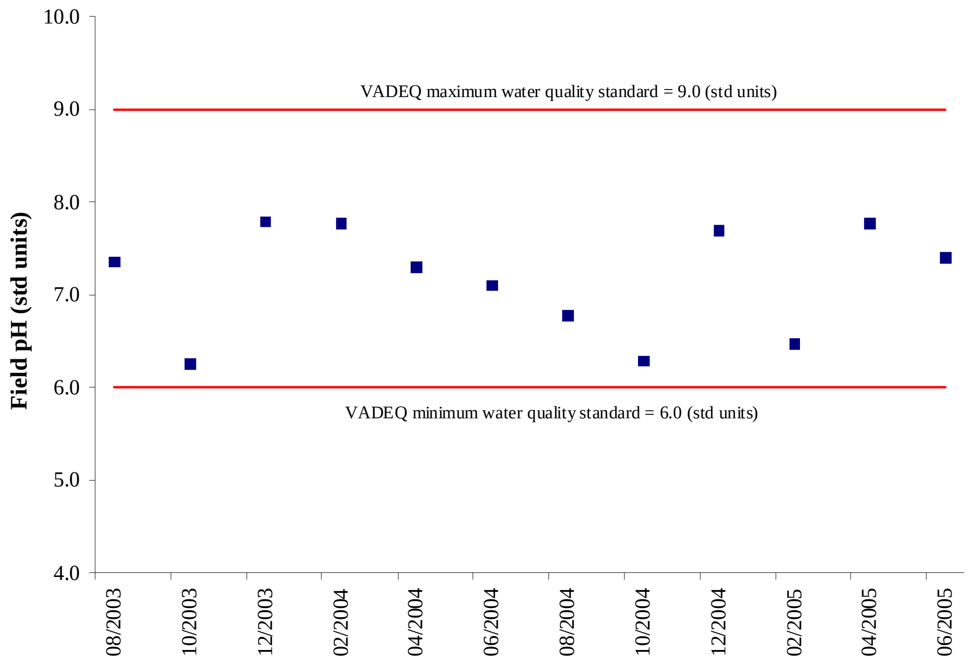

Figure 8.3 Field pH measurements at VADEQ monitoring station 9-MDR000.34.

8.3 Possible Stressors

Table 8.2 Possible Stressors in Meadow Run.

Parameter	Location in Document
Nutrients	Section 8.3.1

8.3.1 Nutrients

Total Phosphorus (TP) concentrations were very low at VADEQ monitoring station 9-MDR000.34 with one exception (Figure 8.4). On June 8, 2004 a total phosphorus concentration of 2.5 mg/L was recorded. This value is more than an order of magnitude higher than VADEQ's screening value (0.2 mg/L). The total suspended solids concentration and turbidity value on June 8, 2004 were 1,816 mg/L and 2,100 NTU, respectively. This is an indication of a large sediment runoff episode in the watershed. In fact, the National Climatic Data Center (NCDC) 449169 located at Willis, Virginia indicated that 1.12 inches of rain fell on June 5, 2004 and additional 0.33 inches on June 8, 2004. This information confirms the likelihood that the high total phosphorus concentration was associated with sediment runoff. The 2008 305(b)/303(d) integrated report stated that this portion of the Little River watershed had a high potential for impacts from nutrient runoff from agricultural land (VADEQ, 2008).

Nitrate nitrogen concentrations were generally low there was maximum concentration of 1.31 mg/L on December 21, 2004 (Figure 8.5). Total nitrogen concentrations averaged 1.39 mg/L (Figure 8.6). Nutrients are considered possible stressors in Meadow Run.

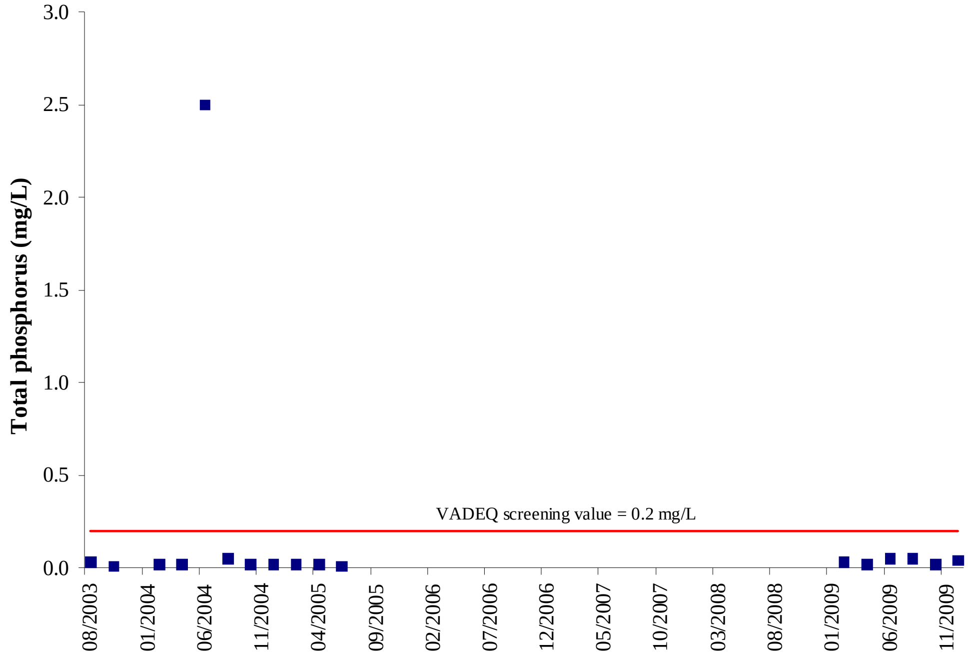

Figure 8.4 Total phosphorus concentrations at VADEQ monitoring station 9-MDR000.34.

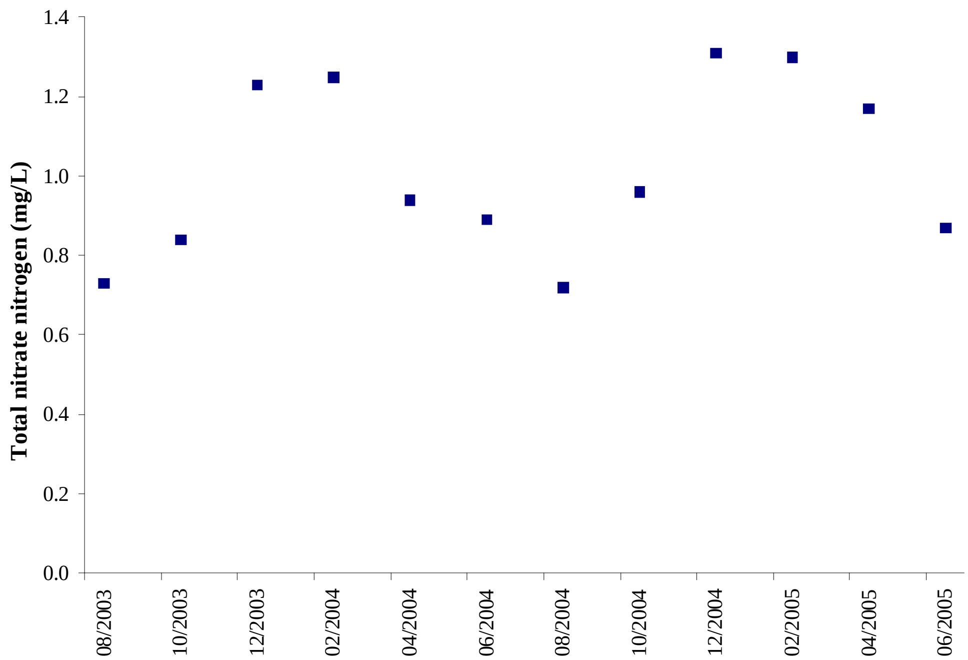

Figure 8.5 Nitrate-nitrogen concentrations at VADEQ station 9-MDR000.34.

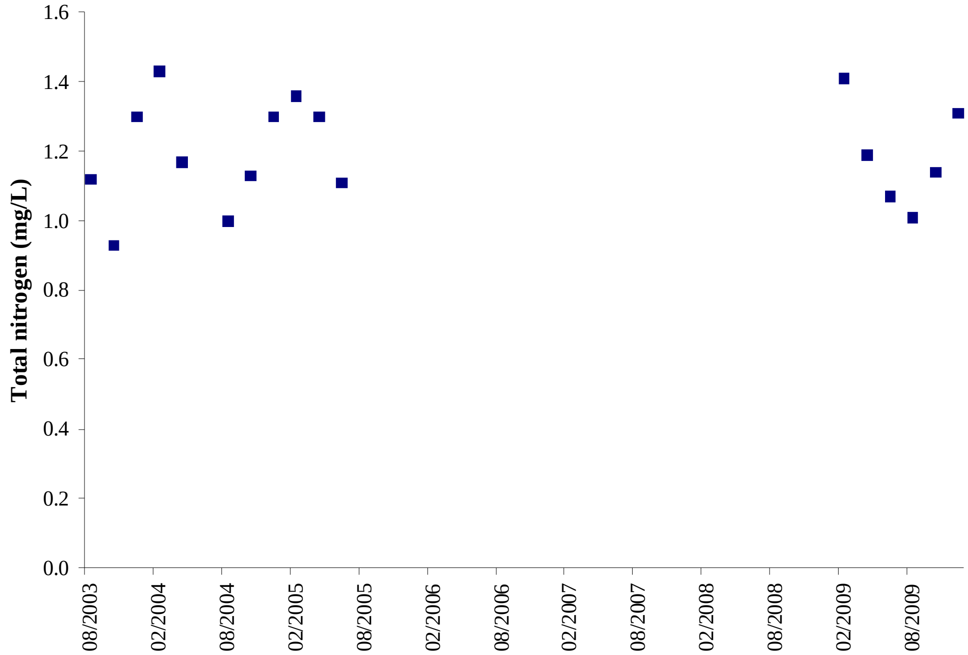

Figure 8.6 Total nitrogen concentrations at VADEQ station 9-MDR000.34.

8.4 Most Probable Stressor

Table 8.3 Probable stressors in Meadow Run.

Parameter	Location in Document
Sediment	Section 8.4.1

8.4.1 Sediment

Total suspended solids (TSS) concentrations were generally low at VADEQ monitoring station 9-MDR000.34 (Figure 8.7). However, an extreme concentration (1,816 mg/L) occurred on June 8, 2004 following periods of high rainfall. This indicates that excessive sediment is a periodic problem in Meadow Run. The 2008 305(b)/303(d) integrated report noted that the VADCR had ranked the Little River watershed as having a high potential for impacts from sediment runoff from agricultural land (VADEQ, 2008).

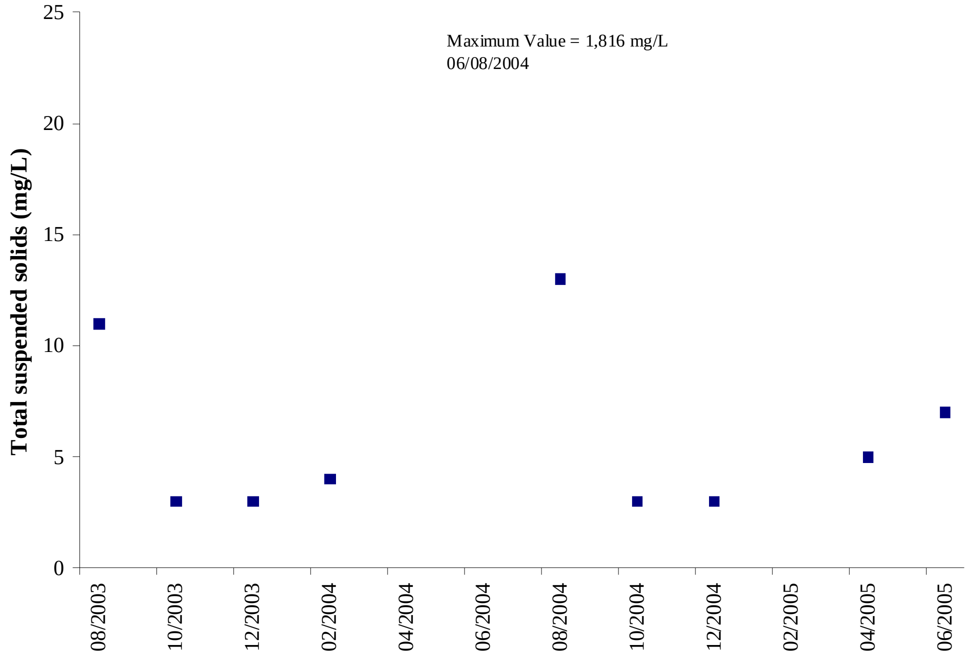

Figure 8.7 Total suspended solids concentrations at VADEQ monitoring station 9-MDR000.34.

The benthic macroinvertebrate community habitat data indicates marginal Pool Sediment scores at probabilistic monitoring station 9-MDR003.60. In addition, the Riparian Vegetation habitat metric scores at this monitoring station were in the poor and marginal categories (Table 6.10). Riparian vegetation measures the width of natural vegetation from the edge of the stream bank out through the riparian zone. The vegetative zone serves as a buffer to pollutants entering a stream from runoff, controls erosion, and provides habitat and nutrient input into the stream (Barbour, 1999). Based on the extreme total suspended solids concentration and marginal Pool Sediment habitat scores, sediment is considered a probable stressor in Meadow Run. Modeling and subsequent TMDL allocations will focus on sediment delivery (tons per year).

9. REFERENCE WATERSHED SELECTION

A reference watershed approach was used to estimate the necessary load reductions that are needed to restore a healthy aquatic community and allow the Little River watershed to achieve the designated uses. This approach is based on selecting a non-impaired watershed that has similar land use, soils, watershed characteristics, area (not to exceed double or not to be less than half the size of the impaired watershed), and located in or near the same ecoregion as the impaired watershed. The modeling process uses load rates or pollutant concentrations in the non-impaired watershed as a target for load reductions in the impaired watershed. The impaired watershed is modeled to determine the current load rates and establish what reductions are necessary to meet the load rates of the non-impaired watershed.

Big Reed Island Creek was selected as the reference stream for the Little River. The reference and impaired watersheds are similar in size and share the same eco-region. Figure 9.1 shows the respective locations of the two watersheds. Table 9.1 shows the land use comparison between the Little River and Big Reed Island Creek. Meadow Run is included in the analysis of Little River using the nested watershed approach since stressor analyses indicated that sediment is the most probable stressor in all impairments.

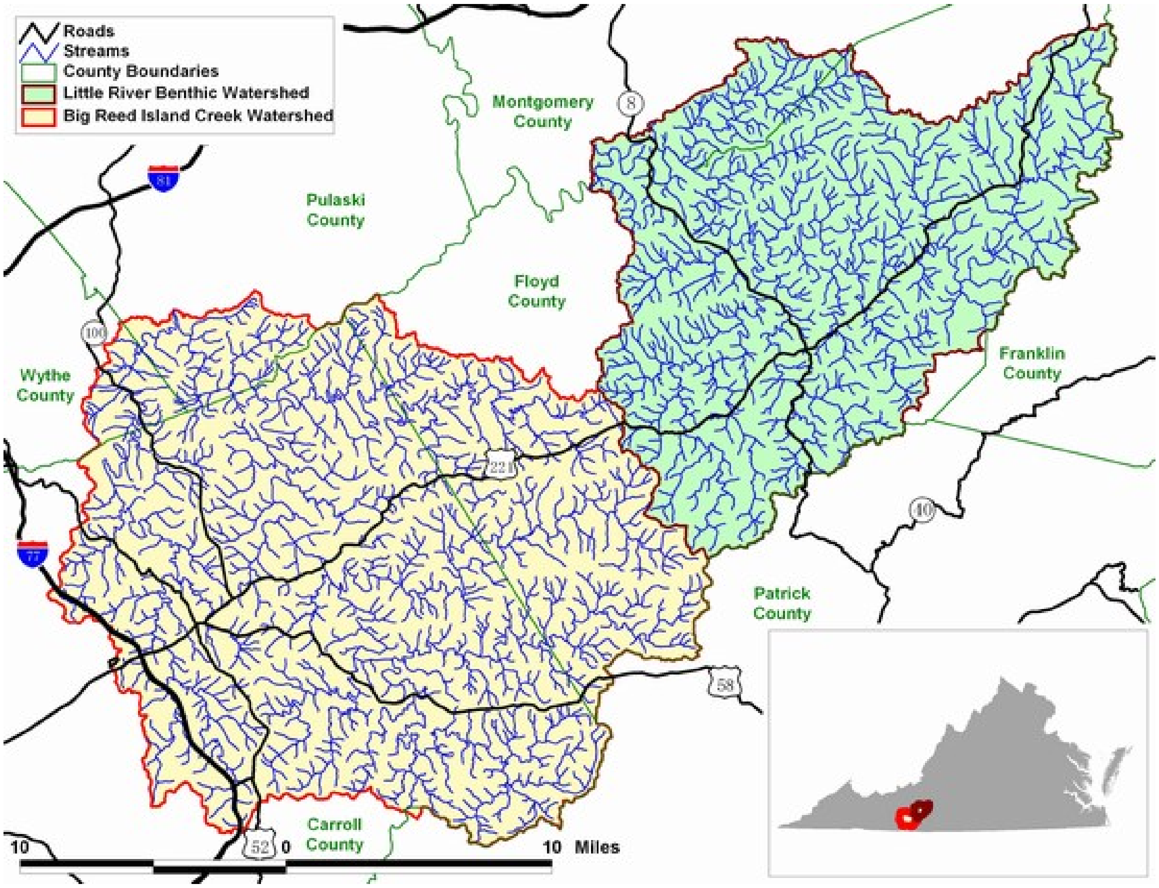

Figure 9.1 Location of the Little River and Big Reed Island Creek watersheds.

Table 9.1 Little River and Big Reed Island Creek land use comparison.

Land use	Little River (Impaired)	Big Reed Island Creek (Reference)
Barren	157	113
Commercial	137	435
Crop	687	463
Developed	8,054	14,008
Forest	84,631	143,921
Pasture	53,558	70,653
Water	949	80
Wetland	215	320
Total Acres	148,388	229,993

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10. MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT- SEDIMENT

10.1 Modeling Framework Selection - GWLF

A reference watershed approach was used in this study to develop a benthic TMDL for sediment for the Little River. As noted in Chapters 7 and 8, sediment was identified as a probable stressor for both Little River and Meadow Run. Since both biological impairments are impacted by high sediment loads, and Meadow Run is a tributary to the Little River, it was decided to nest Meadow Run within the Little River sediment TMDL. A watershed model was used to simulate sediment loads from potential sources in this watershed and in the reference watershed. The model used in this study was the *Visual Basic™* version of the Generalized Watershed Loading Functions (GWLF) model with modifications for use with ArcView (Evans et al., 2001). The GWLF model was developed at Cornell University (Haith and Shoemaker, 1987; Haith, et al., 1992) for use in ungaged watersheds. The model also included modifications made by Yagow et al., (2002) and BSE, (2003). Numeric endpoints were based on unit-area loading rates calculated for the reference watershed. The TMDL was then developed for the impaired watershed based on these endpoints and the results from load allocation scenarios. Parameters are described in the Glossary.

GWLF is a continuous simulation, spatially lumped model that operates on a daily time step for water balance calculations and monthly calculations for sediment and nutrients from daily water balance. In addition to runoff and sediment, the model simulates dissolved and attached nitrogen and phosphorus loads delivered to streams from watersheds with both point and nonpoint sources of pollution. The model considers flow input from both surface and groundwater. Land use classes are used as the basic unit for representing variable source areas. The calculation of nutrient loads from septic systems, stream-bank erosion from livestock access, and the inclusion of sediment and nutrient loads from point sources are also supported. Runoff is simulated based on the Soil Conservation Service's Curve Number method (SCS, 1986). Erosion is calculated from a modification of the Universal Soil Loss Equation (USLE) (Schwab et al., 1981;

Wischmeier and Smith, 1978). Sediment estimates use a delivery ratio based on a function of watershed area and erosion estimates from the modified USLE. The sediment transported depends on the transport capacity of runoff.

For execution GWLF uses three input files for weather, transport, and nutrient loads. The weather file contains daily temperature and precipitation for the period of record. Data was based on a water year starting in October and ending in September. The transport file contains input data related to hydrology and sediment transport. The nutrient file contains nutrient values for the various land uses, point sources, and septic system types, and also urban sediment buildup rates.

10.2 GWLF Model Setup

Watershed data needed to run GWLF used in this study were generated using GIS spatial coverage, local weather data, streamflow data, literature values, and other data. Subwatersheds are not required to run the GWLF model. For the sediment TMDL development, the total area for the reference watershed was equated to the area of impaired watershed. To accomplish this, the area of land use categories in reference watershed was proportionately decreased based on the percentage land use distribution. As a result, the watershed area for the reference watershed was decreased to be equal to the watershed area of the impaired watershed.

The GWLF model was developed to simulate runoff, sediment and nutrients in ungaged watersheds based on landscape conditions such as land use/land cover, topography, and soils. In essence, the model uses a form of the hydrologic units (HU) concept to estimate runoff and sediment from different pervious areas (HUs) in the watershed (Li, 1975; England, 1970). In the GWLF model, the nonpoint source load calculation for sediment is affected by land use activity (*e.g.*, farming practices), topographic parameters, soil characteristics, soil cover conditions, stream channel conditions, livestock access, and weather. The model uses land use categories as the mechanism for defining homogeneity of source areas. This is a variation of the HU concept, where homogeneity in hydrologic response or nonpoint source pollutant response would typically involve the identification of soil land use topographic conditions that would be expected to give a homogeneous response to a given rainfall input. A number of parameters are included in the model to index the effect of varying soil-topographic conditions by land use entities. A description of model parameters is given in the Glossary and a description of how parameters and other data were calculated and/or assembled is below.

10.2.1 Sediment Source Assessment

Three source areas were identified as the primary contributors to sediment loading in Little River that are the focus of this study – surface runoff, point sources, and streambank erosion. The sediment process is a continual process but is often accelerated by human activity. An objective of the TMDL process is to minimize the acceleration process. This section describes predominant sediment source areas, model parameters, and input data needed to simulate sediment loads.

10.2.1.1 Surface Runoff

During runoff events (natural rainfall or irrigation), sediment is transported to streams from pervious land areas (*e.g.,* agricultural fields, lawns, forest.). Rainfall energy, soil cover, soil characteristics, topography, and land management affect the magnitude of sediment loading. Agricultural management activities such as overgrazing (particularly on steep slopes), high tillage operations, livestock concentrations (*e.g.,* along stream edge, uncontrolled access to streams), forest harvesting, and land disturbance due to mining and construction (roads, buildings, etc.) all tend to accelerate erosion at varying degrees. During dry periods, sediment from air or traffic builds up on impervious areas and is transported to streams during runoff events. The magnitude of sediment loading from this source is affected by various factors (*e.g.,* the deposition from wind erosion and vehicular traffic).

10.2.1.2 Channel and Streambank Erosion

An increase in impervious land without appropriate stormwater control increases runoff volume and peaks, which leads to greater channel erosion potential. It has been well documented that livestock with access to streams can significantly alter physical dimensions of streams through trampling and shearing (Armour et al., 1991; Clary and Webster, 1989; Kaufman and Kruger, 1984). Increasing the bank full width decreases stream depth, increases sediment, and adversely affects aquatic habitat (USDI, 1998). Management practices that allow mowing, paving, building or material storage up to the edge of a stream or bank cause instability also. These practices do not allow natural stream migration along the floodplain and allow room for flood waters to dissipate. This makes banks and stream segments unstable and erosion from banks more prominent.

10.2.1.3 TSS Point Sources

Sediment loads from permitted wastewater, industrial, and construction stormwater dischargers, and mining operations are included in the WLA component of the TMDL, in compliance with 40 CFR§130.2(h). Fine sediments are included in TSS loads that are permitted for various facilities, industrial and construction stormwater, and VPDES permits within the Little River watershed.

The TSS loading from uncontrolled discharges (straight pipes) was accounted for in the sediment TMDL. A TSS concentration from human waste was estimated as 320 mg/L (Lloyd, 2004) at 75 gal of waste water per day per person.

10.2.2 Sediment Source Representation – Input Requirements

As described in Section 10.2, the GWLF model was developed to simulate runoff, sediment and nutrients in ungaged watersheds based on landscape conditions such as land use/land cover, topography, and soils. The following sections describe required inputs for the GWLF program.

10.2.2.1 Streamflow and Weather data

Daily precipitation data was available within the Little River watershed at the Floyd 2 NE NCDC Coop station # 443071. Missing values were filled using daily precipitation from the Willis NCDC Coop station # 449169 and Christiansburg NCDC Coop station 441692.

10.2.2.2 Land use and Land cover

Land use distributions for the Little River watershed, and for the area-adjusted Big Reed Island Creek watershed are given in Table 10.1. Land use acreage for the reference watersheds were adjusted down by the ratio of impaired watershed to reference watershed maintaining the original land use distribution. These areas were used for modeling sediment.

Table 10.1 Land use areas used in the GWLF model for the Little River and area-adjusted Big Reed Island Creek watersheds.

Sediment Source	Little River	Area Adjusted Big Reed Island Creek
	(ha)[1]	(ha)
Pervious Area:		
Barren	57.17	26.65
Commercial	22.16	45.77
High Tillage	29.64	31.23
Low Tillage	248.45	90.49
Developed	2282.37	2577.05
Forest	33432.83	37126.71
Disturbed Forest	830.74	697.88
Hay	6114.54	5254.50
Cattle-Grazed Pasture	11746.86	10547.00
Unimproved Pasture	4192.16	2767.30
Water	384.06	21.14
Wetland	87.13	84.08
Impervious Area:		
Barren	6.35	2.96
Commercial	33.24	68.65
Developed	978.16	1104.45
Watershed Total	**60,445.86**	**60,445.86**

[1] 1ha = 2.47 ac

10.2.2.3 Sediment Parameters

Sediment parameters include USLE parameters erodibility factor (K), length of slope (LS), cover crop factor (C), and practice factor (P), sediment delivery ratio, and a buildup and loss functions for impervious surfaces. The product of the USLE parameters, KLSCP, is entered as input to GWLF. Soils data for the watersheds were obtained from the Soil Survey Geographic (SSURGO) database for Virginia (NRCS, 2010a). The K factor relates to a soil's inherent erodibility and affects the amount of soil erosion from a given field. The area-weighted K-factor by land use category was calculated using GIS procedures. Land slope was calculated from USGS National Elevation Dataset data using GIS techniques. The length of slope was estimated using GIS procedures developed by MapTech, Inc that consider the path of flow in raster-based GIS. The area-weighted LS factor was calculated for each land use category using procedures recommended by Wischmeier and Smith (1978). The weighted C-factor for each land use category was estimated following guidelines given in Wischmeier and Smith, 1978, GWLF User's Manual (Haith et al., 1992) and Kleene, 1995. The practice factor (P) was set at 1.0 for all land.

10.2.2.4 Sediment Delivery Ratio

The sediment delivery ratio specifies the percentage of eroded sediment delivered to surface water and is empirically based on watershed size. The sediment delivery ratios for impaired and reference watersheds were calculated as an inverse function of watershed size (Evans et al., 2001). The value used for the Little River and Big Reed Island Creek watersheds was 0.067.

10.2.2.5 SCS Runoff Curve Number

The runoff curve number is a function of soil type, antecedent moisture conditions, and cover and management practices. The runoff potential of a specific soil type is indexed by the Soil Hydrologic Group (SHG) code. Each soil-mapping unit is assigned SHG codes that range in increasing runoff potential from A to D. The SHG code was given a numerical value of 1 to 4 to index SHG codes A to D, respectively. An area-weighted average SHG code was calculated for each land use/land cover from soil survey data using GIS techniques. Runoff curve numbers (CN) for SHG codes A to D were assigned to each land use/land cover condition for antecedent moisture condition II following GWLF guidance documents and SCS, 1986 recommended procedures. The runoff CN for each land use/land cover condition then was adjusted based on the numeric area-weighted SHG codes.

10.2.2.6 Parameters for Channel and Streambank Erosion

Parameters for streambank erosion include animal density, total length of streams with livestock access, total length of natural stream channel, fraction of developed land, mean stream depth, and watershed area. The animal density was calculated by dividing the number of animal units (beef and dairy) by watershed area in acres. The total length of the natural stream channel was estimated from USGS NHD hydrography coverage using GIS techniques. The mean stream depth was estimated as a function of watershed area.

10.2.2.7 Evapo-transpiration Cover Coefficients

Evapotranspiration (ET) cover coefficients were entered by month. Monthly ET cover coefficients were assigned each land use/land cover condition following procedures outlined in Novotny and Chesters (1981) and GWLF guidance. Area-weighted ET cover coefficients were then calculated for each sediment source class. These values were then adjusted during hydrology calibration.

10.2.2.8 TSS Permitted and Direct Sources

Construction stormwater permitted loads were calculated as the average annual modeled runoff times the area governed by the permit times a maximum TSS concentration of 100 mg/l. The modeled runoff for the construction stormwater discharge was estimated as equal to the annual runoff from the barren area. The modeled runoff for the industrial stormwater discharge was estimated as equal to the annual runoff from the developed area. For the construction and industrial permits, the average annual runoff (cm/yr) was multiplied by the permit area (ha), multiplied by the permitted TSS concentration (100 mg/L), and were multiplied by conversion factors to get a permit load in metric tons per year (t/yr). For the domestic wastewater treatment, carwashes, and VPDES permits, the design discharge was multiplied by the permitted TSS concentration and then multiplied by conversion factors to get a permit load in metric tons per year (t/yr). Each of the domestic wastewater treatment (DWT) permits was calculated separately as noted. All permitted loads are shown in Tables 10.2.

Table 10.2 Permitted Sources in the Little River watershed.

Permit Number	Permit Type	Sediment (t/yr)
VAR100025	Construction	0.32
VAR100026	Construction	0.29
VAR100027	Construction	0.53
VAR100101	Construction	0.24
VAR101037	Construction	0.34
VAR101084	Construction	0.25
VAR101282	Construction	0.24
VAR101282	Construction	0.34
VAR101282	Construction	0.34
VAR101283	Construction	0.28
VAR101527	Construction	0.24
VAR101752	Construction	0.16
VAR102803	Construction	0.15
VA0025992	VPDES	6.22
VA0025992	VPDES	16.59
VAG402042	Domestic	0.04
VAG402018	Domestic	0.04
VAG402051	Domestic	0.04
Total		***26.65***

10.2.3 Selection of Representative Modeling Period - GWLF

An analysis of historic precipitation and streamflow in Little River was preformed to select a representative time frame. The time period chosen was water year 2006 through water year 2008.

10.3 GWLF Sensitivity Analyses

Sensitivity analyses were conducted to assess the sensitivity of the model to changes in hydrologic and water quality parameters as well as to assess the impact of unknown variability in source allocation (*e.g.*, seasonal and spatial variability of land disturbance, runoff curve number, etc.). Sensitivity analyses were run on the runoff curve number (CN), the combined erosion factor (KLSCP) that combines the effects of soil erodibility, land slope, land cover, and management practices, the recession coefficient, the seepage coefficient, the unsaturated available water capacity (AWC), and the Evapotranspiration (ET) Coefficient (Table 10.3).

Table 10.3 Base parameter values used in GWLF sensitivity analysis.

Land use	CN	KLSCP	Recession Coefficient (1/d)	Seepage Coefficient (1/d)	Unsaturated Available Water Capacity (AWC)	Evapotrans-piration (ET) Coefficient
Entire Watershed			0.1	0.1	10	0.5 – 1.0
Pervious Area:						
Barren	84.32	0.295494				
Commercial	63.89	0.00181				
High Tillage	78.44	0.130995				
Low Tillage	74.62	0.057682				
Developed	62.05	0.00847				
Forest	56.82	0.002353				
Disturbed Forest	67.33	0.131494				
Hay	59.26	0.002999				
Cattle-Grazed Pasture	62.27	0.009687				
Unimproved Pasture	69.98	0.055888				
Impervious Area:						
Barren	98.0	0.295494				
Commercial	98.0	0.00181				
Developed	98.0	0.00847				

For a given simulation, the model parameters in Table 10.3 were set at the base value except for the parameter being evaluated. The parameters were adjusted individually to -10% and +10% of the base value and then the output values from the base run and the adjusted run were compared. The results in Table 10.4 show that the parameters are directly correlated with runoff volume and sediment load. The relationships show fairly linear responses with the exception of curve number. Changes in KLSCP had no impact on hydrology and fairly considerable impact on sediment load. Changes in curve numbers have the most influence on both the flow and sediment load. Changes in other hydrologic parameters had more impact on runoff volume than on sediment load with evapotranspiration rates having the second largest impact on hydrology after curve numbers.

Table 10.4 Sensitivity of GWLF model response to changes in selected parameters for Little River.

Model Parameter	Parameter Change (%)	Total Runoff Volume Percent Change (%)	Total Sediment Load Percent Change (%)
CN	10	6.5%	27.1%
CN	-10	-4.9%	-12.8%
KLSCP	10	0.0%	7.6%
KLSCP	-10	0.0%	-7.6%
Recession Coefficient	10	4.0%	0.5%
Recession Coefficient	-10	-4.4%	-0.5%
Seepage Coefficient	10	4.4%	0.6%
Seepage Coefficient	-10	-4.0%	-0.5%
ET Coefficient	10	-5.5%	-0.8%
ET Coefficient	-10	5.8%	0.8%
Unsaturated AWC	10	-2.5%	-0.5%
Unsaturated AWC	-10	2.5%	0.4%

10.4 GWLF Hydrology Calibration

Although the GWLF model was originally developed for use in ungaged watersheds, calibration was performed to ensure that hydrology was being simulated accurately. This process was performed in order to minimize errors in sediment simulations due to potential gross errors in hydrology. The model's parameters were assigned based on available soils, land use, and topographic data. Parameters that were adjusted during calibration included the recession constant, the monthly evapotranspiration cover coefficients, the unsaturated soil moisture storage, and the seepage coefficient.

10.4.1 Little River – Impaired Stream

The final GWLF calibration results for Little River are displayed in Figures 10.1 and 10.2 for the calibration period with statistics showing the accuracy of fit given in the Table 10.5. Model calibration was considered good for total runoff volume (Table 10.5). Monthly fluctuations were variable but were still reasonable considering the general simplicity of GWLF.

Table 10.5 GWLF flow calibration statistics for Little River.

Watershed	Simulation Period	R^2 Correlation value	Total Volume Error (Sim-Obs)
Little River	10/1/2005 – 9/30/2008	0.87	0.15%

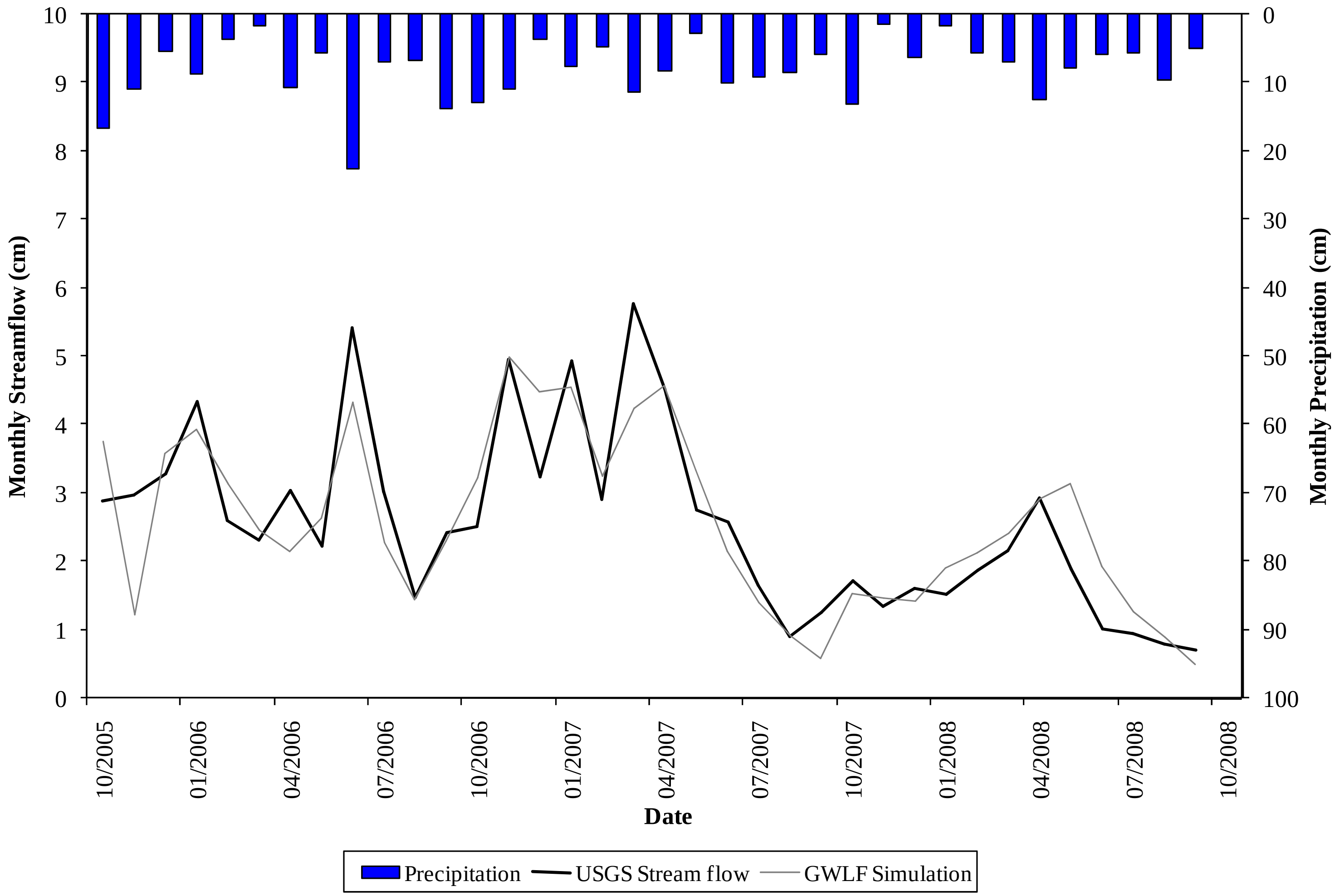

Figure 10.1 Comparison of monthly GWLF simulated (Modeled) and monthly USGS (Observed) streamflow in Little River.

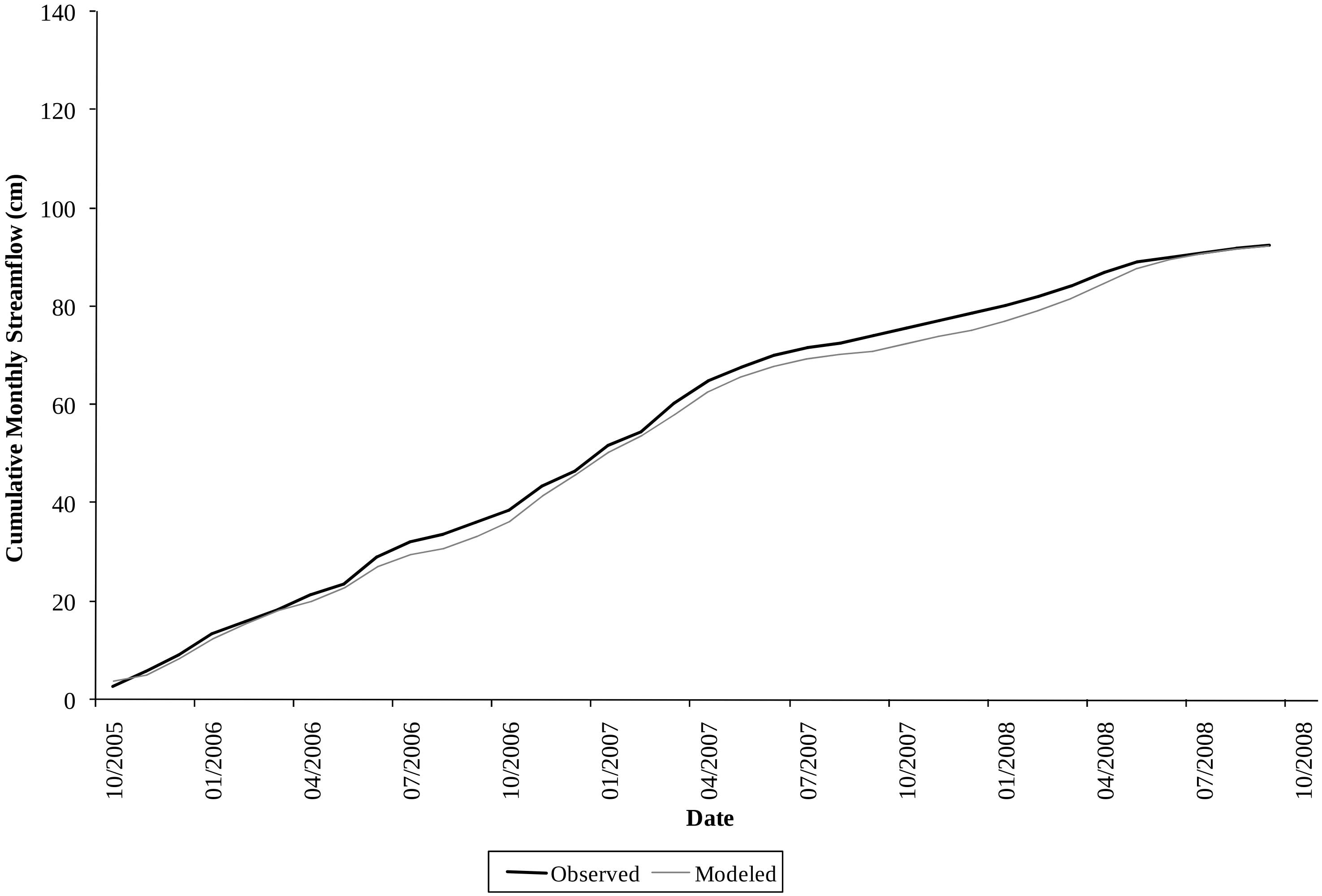

Figure 10.2 Comparison of cumulative monthly GWLF simulated (Modeled) and cumulative USGS (Observed) streamflow in Little River.

The GWLF model was validated for the period of 10/1/1993 to 9/30/1996. Results for Little River hydrology validation are displayed in Figures 10.1 and 10.2 with statistics showing the accuracy of fit given in the Table 10.5. Model validation was considered good for total runoff volume (Table 10.5). Monthly fluctuations were variable but were still reasonable considering the general simplicity of GWLF.

Table 10.6 GWLF flow validation statistics for Little River.

Watershed	Simulation Period	R^2 Correlation value	Total Volume Error (Sim-Obs)
Big Reed Island Creek	10/1/1992 – 9/30/1996	0.79	-6.7%

10.4.2 Big Reed Island Creek – Reference Stream

No useful observed flow station existed on Big Reed Island Creek. Therefore, paired watershed approach was used. In paired watershed approach, the model's hydrologic parameters for the reference watershed were modeled after those of the impaired watershed. The paired and reference watersheds share similar land use and eco-region and are also adjacent to one another.

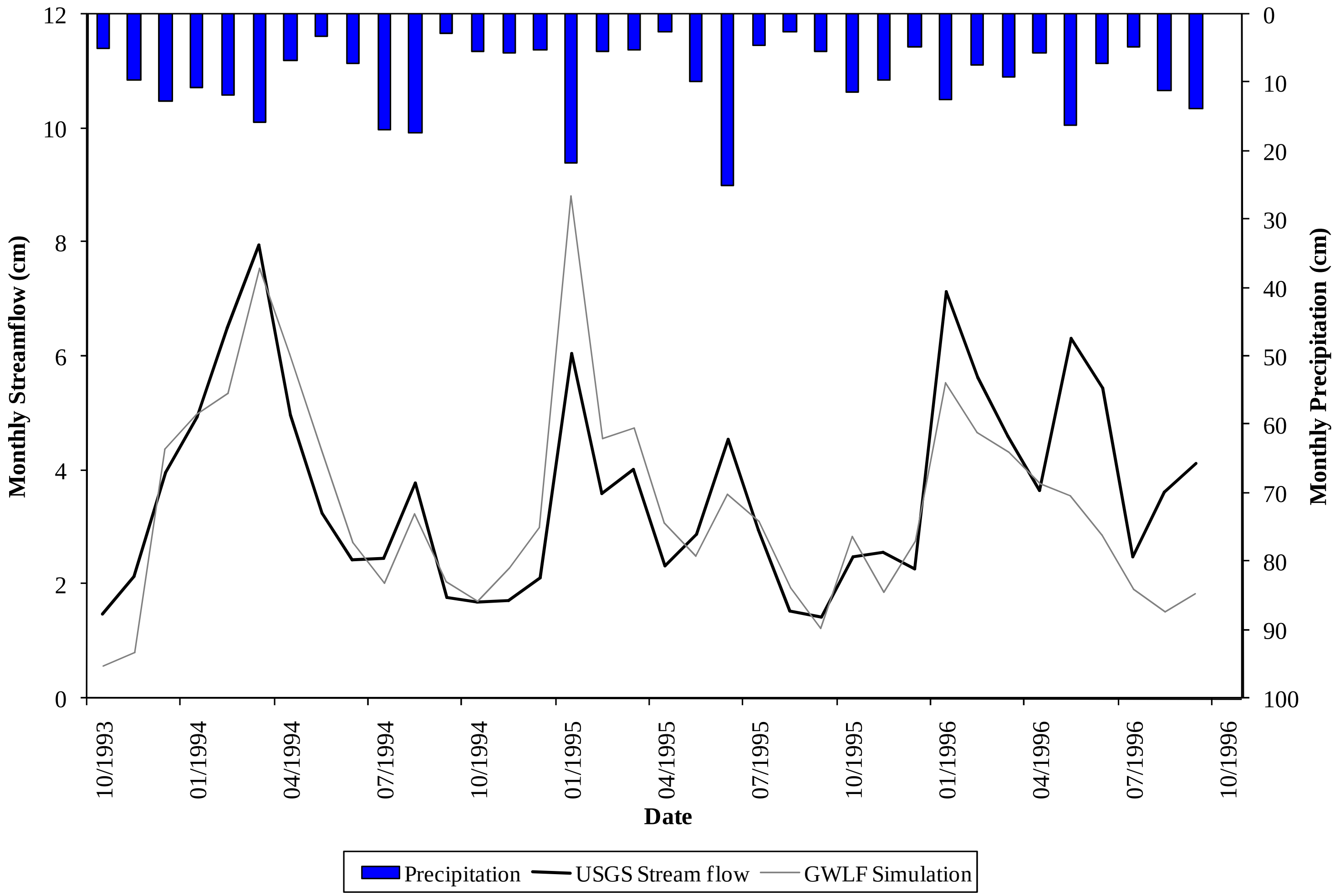

Figure 10.3 Comparison of monthly GWLF simulated (Modeled) and monthly USGS (Observed) streamflow in Little River for validation period.

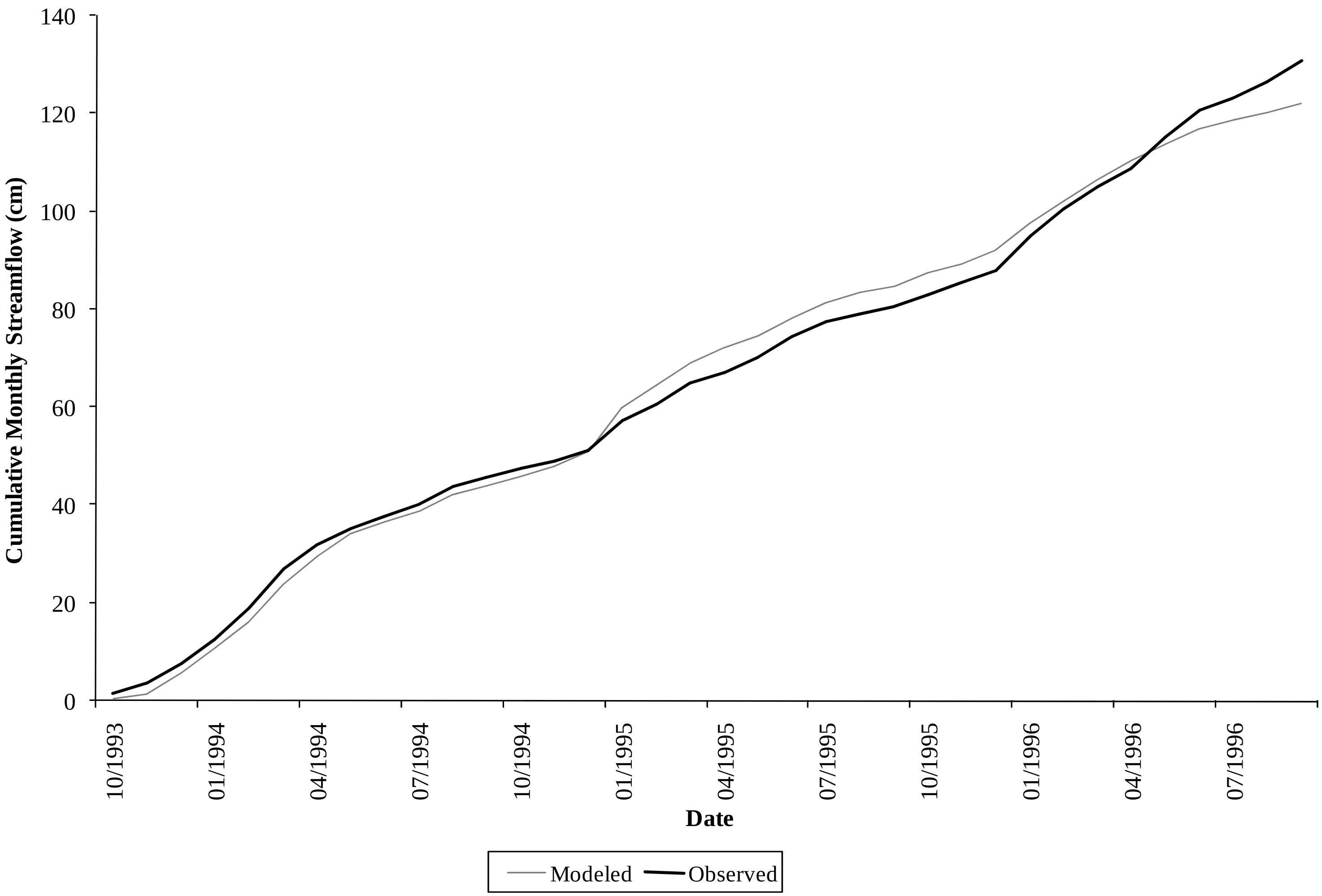

Figure 10.4 Comparison of cumulative monthly GWLF simulated (Modeled) and cumulative USGS (Observed) streamflow in Little River for validation period.

10.5 Sediment Existing Conditions

A list of parameters from the GWLF transport input files that were finalized for existing conditions are given in Table 10.7. Monthly evaporation cover coefficients are listed in Table 10.8.

Table 10.7 GWLF watershed parameters in the calibrated impaired and reference watersheds.

GWLF Watershed Parameter	Units	Little River	Big Reed Island Creek
Recession Coefficient	Day^{-1}	0.1	0.1
Seepage Coefficient	Day^{-1}	0.0	0.0
Sediment Delivery Ratio	---	0.067	0.067
Unsaturated Water Capacity	(cm)	12.97	11.28
Rainfall Erosivity Coefficient (Apr-Sep)	---	0.3	0.3
Rainfall Erosivity Coefficient (Oct-Mar)	---	0.11	0.11
% Developed land	(%)	1.7	1.9
Livestock density	(AU/ac)	0.134	0.075
Area-weighted soil erodibility (K)	---	0.21	0.22
Area-weighted Curve Number	---	60.5	64.8
Total Stream Length	(m)	1,021,207	970,600
Mean channel depth	(m)	1.5	1.5

Table 10.8 Calibrated GWLF monthly evaporation cover coefficients.

Watershed	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Little River	0.5	1.2	0.8	0.8	0.5	0.2	0.3	0.05	0.6	0.6	0.6	0.5
Big Reed Island Creek	0.5	1.2	0.8	0.8	0.5	0.2	0.3	0.05	0.6	0.6	0.6	0.5

Table 10.9 lists the area-weighted USLE erosion parameter (KLSCP) and runoff curve number by land use for each watershed. The curve number values are area weighted by land use.

Table 10.9 The GWLF curve numbers and KLSCP values for existing conditions in the Little River and Big Reed Island Creek watersheds.

	Little River		Big Reed Island Creek	
Sediment Source	**CN**	**KLSCP**	**CN**	**KLSCP**
Pervious Area:				
Barren	84.32	0.295494	85.61	0.623137
Commercial	63.89	0.00181	66.01	0.001841
High Tillage	78.44	0.130995	79.82	0.138458
Low Tillage	74.62	0.057682	76.55	0.060969
Developed	62.05	0.00847	65.9	0.009813
Forest	56.82	0.002353	63.25	0.002889
Disturbed Forest	67.33	0.131494	72.05	0.168606
Hay	59.26	0.002999	62.14	0.003161
Cattle-Grazed Pasture	62.27	0.009687	65.14	0.010274
Unimproved Pasture	69.98	0.055888	72.18	0.059273
Water	98	0	98	0
Wetland	57.62	0.002053	61.58	0.003145
Impervious Area:				
Barren	98.0	0.295494	98.0	0.623137
Commercial	98.0	0.00181	98.0	0.001841
Developed	98.0	0.00847	98.0	0.009813

The sediment loads were modeled for existing conditions in Little River and the reference watershed, Big Reed Island Creek. The existing condition is the combined sediment load, which compares to the area-adjusted reference watershed load (Table 10.10).

Table 10.10 Existing sediment loads for Little River and area-adjusted Big Reed Island Creek watersheds.

Sediment Source	Little River		Reference Watershed Area-Adjusted Big Reed Island Creek	
	t/yr	t/ha/yr	t/yr	t/ha/yr
Pervious Area:				
Barren	300.14	5.25	299.73	11.25
Commercial	2.81	0.13	3.26	0.07
High Tillage	61.56	2.08	68.89	2.21
Low Tillage	206.53	0.83	81.61	0.90
Developed	185.60	0.08	250.50	0.10
Forest	626.28	0.02	1026.21	0.03
Disturbed Forest	1089.33	1.31	1391.79	1.99
Hay	152.96	0.03	158.91	0.03
Cattle-Grazed Pasture	1092.52	0.09	1036.75	0.10
Unimproved Pasture	2517.24	0.60	1940.14	0.70
Water	0.00	0.00	0.00	0.00
Wetland	1.49	0.02	2.39	0.03
Impervious Area:				
Barren	1.23	0.19	0.57	0.19
Commercial	6.42	0.19	13.25	0.19
Developed	188.76	0.19	213.14	0.19
Direct Sources:				
Streambank Erosion	2,824.54		2,550.51	
Straight Pipes	15.26		28.23	
Permitted Sources:				
DEQ Permits	26.65		8.75	
Watershed Total	**9,299.32**		**9,074.63**	

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11. SEDIMENT ALLOCATION

Total Maximum Daily Loads consist of waste load allocations (WLAs, permitted point sources) and load allocations (LAs, nonpermitted sources), including natural background levels. Additionally, the TMDL must include a margin of safety (MOS) that either implicitly or explicitly accounts for uncertainties in the process. The definition is typically denoted by the expression:

$$\text{TMDL} = \text{WLAs} + \text{LAs} + \text{MOS}$$

The TMDL becomes the amount of a pollutant that can be assimilated by the receiving water body and still achieve water quality standards. For sediment, the TMDL is expressed in terms of annual load in metric tons per year (t/yr).

The Little River sediment TMDL was developed using Big Reed Island Creek as a reference watershed. The models were run over the period of 10/1/2005 to 9/30/2008 for modeling sediment allocations. The target sediment TMDL load for the Little River is the average annual load in metric tons per year (t/yr) from the area-adjusted Big Reed Island Creek watershed under existing conditions minus a Margin of Safety (MOS).

11.1 Margin of Safety

In order to account for uncertainty in modeled output, an MOS was incorporated into the TMDL development process. Individual errors in model inputs, such as data used for developing model parameters or data used for calibration, may affect the load allocations in a positive or a negative way. For example, the typical method of assessing water quality through monitoring involves the collection and analysis of grab samples. The results of water quality analyses on grab samples collected from the stream may or may not reflect the "average" condition in the stream at the time of sampling. Calibration to observed data derived from grab samples introduces modeling uncertainty.

An MOS can be incorporated implicitly in the model through the use of conservative estimates of model parameters, or explicitly as an additional load reduction requirement. The MOS for the sediment TMDLs was explicitly expressed as 10% of the area-adjusted reference watershed load. An explicit MOS was incorporated for the Little River watershed.

11.2 Future Growth Considerations

The land use in the Little River watershed is not expected to change significantly in the next 25 years. The Little River watershed is mostly rural with the exception of the Town of Floyd and it is assumed that residential and commercial growth in the watershed will not have considerable impact on future sediment loads.

A sediment load value for future growth was determined as 1% of the total TMDL. This was incorporated into the WLA for use as current discharges expand and for future permits that may discharge sediment.

11.3 Sediment TMDL

The target TMDL load for Little River is the average annual load in metric tons per year (t/yr) from the area-adjusted Big Reed Island Creek watershed under existing conditions. To reach the TMDL target load, three different scenarios were run (Table 11.1). Sediment loads from straight pipes were reduced 100% in all scenarios due to health implications and the requirements of the fecal bacteria TMDL. Scenario 1 shows similar reductions to sediment loads from barren lands, high tillage, unimproved pasture, disturbed forest, and streambank erosion. Scenario 2 shows reductions to loads only from straight pipes and streambank erosion. Scenario 3 shows reductions to loads from streambank erosion and unimproved pasture. All three scenarios meet the TMDL goal at a total sediment load reduction of 12.18%. Scenario 1 was chosen to use for the final TMDL because it has reasonable reductions on all types of land uses.

Table 11.1 Final TMDL allocation scenario for the impaired Little River watershed.

Sediment Source	Existing Little Loads t/yr	Scenario 1 Reductions (Final) (%)	Scenario 1 Allocated Loads t/yr	Scenario 2 Reductions (%)	Scenario 2 Loads t/yr	Scenario 3 Reductions (%)	Scenario 3 Loads t/yr
Barren	300.14	**17.77%**	246.81		300.14		300.14
Commercial	2.81		2.81		2.81		2.81
High Tillage	61.56	**17.77%**	50.62		61.56		61.56
Low Tillage	206.53		206.53		206.53		206.53
Developed	185.60		185.60		185.60		185.60
Forest	626.28		626.28		626.28		626.28
Disturbed Forest	1,089.33	**17.77%**	895.76		1,089.33		1,089.33
Hay	152.96		152.96		152.96		152.96
Cattle-Grazed Pasture	1,092.52		1,092.52		1,092.52		1,092.52
Unimproved Pasture	2,517.24	**17.77%**	2,069.93		2,517.24	**22.60%**	1,948.34
Water	0.00		0.00		0.00		0.00
Wetland	1.49		1.49		1.49		1.49
Impervious Area:							
Barren	1.23		1.23		1.23		1.23
Commercial	6.42		6.42		6.42		6.42
Developed	188.76		188.76		188.76		188.76
Direct Sources:							
Streambank Erosion	2,824.54	**17.77%**	2,322.62	**42.73%**	1,617.61	**22.60%**	2,186.19
Straight Pipes	15.26	**100.00%**	0.00	**100.00%**	0.00	**100.00%**	0.00
Permitted Sources:							
DEQ Permits	26.65		26.65		26.65		26.65
Future Growth			89.84		89.85		89.84
Margin of Safety			907.46		907.46		907.46
Watershed Total	**9,299.32**	**12.18%**	**9,074.47**	**12.18%**	**9,074.44**	**12.18%**	**9,074.11**

The final overall sediment load reduction required for the Little River is 12.19% (Table 11.2).

Table 11.2 Required sediment reductions for Little River.

Load Summary	Little River (t/yr)	Reductions Required (t/yr)	(% of existing load)
Existing Sediment Load	9,299.32		
Target Modeling Load (LA+WLA)	8,166.83	1132.49	12.18%

The sediment TMDL for Little River includes three components – WLA, LA, and the 10% MOS. The WLA was calculated as the sum of all permitted point source discharges. The LA was calculated as the target TMDL load minus the WLA load minus the MOS (Table 11.3).

Table 11.3 Average annual sediment TMDL for Little River.

Impairment	WLA t/yr	LA t/yr	MOS t/yr	TMDL t/yr
Little River	**116.49**	**8,050.34**	**907.46**	**9,074.29**
VAR100025	0.32			
VAR100026	0.29			
VAR100027	0.53			
VAR100101	0.24			
VAR101037	0.34			
VAR101084	0.25			
VAR101282	0.24			
VAR101282	0.34			
VAR101282	0.34			
VAR101283	0.28			
VAR101527	0.24			
VAR101752	0.16			
VAR102803	0.15			
VA0025992	6.22			
VA0025992	16.59			
VAG402042	0.04			
VAG402018	0.04			
VAG402051	0.04			
Future Growth	*89.84*			

* WLA is expressed as the summation of all individual permit loads.

Starting in 2007, the USEPA has mandated that TMDL studies include a maximum "daily" load (MDL) as well as the average annual load previously shown. The approach to developing a daily maximum load was similar to the USEPA approved approach found in the 2007 document titled Options for Expressing Daily Loads in TMDLs (USEPA, 2007). The procedure involved calculating the MDL from the long-term average annual TMDL load in addition to a coefficient of variation (VC) estimated from the annual load for ten years. The annual sediment load ranged from 4,583 t to 24,737 t with a coefficient of variation (CV) of 0.48. A multiplier was used to estimate the MDL from the long-term average based on the USEPA guidance. The multiplier estimated for the Little River was 3.23. In this case, the long-term average was the annual TMDL divided by 365.25 days (24.84 t/day) resulting in a MDL of 80.147 t/day. The daily WLA for individual permits was estimated as the annual WLA divided by 365.25 and future growth estimated at one percent of the MDL. The daily MOS was estimated as 10% of the MDL. Finally, the daily LA was estimated as the MDL minus the daily MOS minus the daily WLA. These results are shown in Table 11.4.

Table 11.4 Maximum daily sediment loads (t/day) for Little River.

Impairment	WLA t/yr	LA t/yr	MOS t/yr	TMDL t/yr
Little River	**0.874**	**71.258**	**8.015**	**80.147**
DEQ VPDES permits:				
VAR100025	0.001			
VAR100026	0.001			
VAR100027	0.001			
VAR100101	0.001			
VAR101037	0.001			
VAR101084	0.001			
VAR101282	0.001			
VAR101282	0.001			
VAR101282	0.001			
VAR101283	0.001			
VAR101527	0.001			
VAR101752	0.000			
VAR102803	0.000			
VA0025992	0.017			
VA0025992	0.045			
VAG402042	0.000			
VAG402018	0.000			
VAG402051	0.000			
Future Growth	0.801			

* WLA is expressed as the summation of all individual permit loads.

12. TEMPERATURE

12.1 Background

A total of eight stream segments are listed as impaired for violating the state's temperature standards. Five of the segments, including three on the mainstem of the Little River, West Fork Dodd Creek, and Pine Creek, are in violation of the natural trout waters maximum temperature standard of 20 ^{o}C. The remaining three segments, including two segments on Dodd Creek and one segment on Big Indian Creek, are in violation of the stockable trout waters maximum temperature standard of 21 ^{o}C.

The cause of the impairments is attributed to natural conditions. There are no known sources of heat within the watershed that may result in the violations except natural solar radiation.

12.2 Temperature Standards

The criteria which were used in developing the temperature TMDL in this study are outlined in Section 9VAC25-260-50 (Numerical criteria for dissolved oxygen, pH, and maximum temperature). According to this section, the maximum temperature in natural trout waters shall not exceed 20 ^{o}C. For stockable trout waters, the maximum temperature shall not exceed 21 ^{o}C.

12.3 Selection of Temperature TMDL Endpoint

An important step in developing a TMDL is the establishment of in-stream numeric endpoints, which are used to evaluate the attainment of acceptable water quality. In-stream numeric endpoints, therefore, represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. For the temperature impairments in the Little River watershed, the applicable endpoints and associated target values can be determined directly from the Virginia water quality regulations.

In order to remove a waterbody from a state's list of impaired waters, the Clean Water Act requires compliance with that state's water quality standard. The in-stream temperature target for the TMDLs in this study was a maximum simulated temperature not exceeding 20 °C and 21 °C for natural trout waters and stockable trout waters, respectively.

12.4 Discussion of In-Stream Water Quality

The VADEQ provided observed temperature data for 12 monitoring stations on the Little River and its tributaries. Summary of data from in-stream water samples, collected at the 12 VADEQ monitoring stations (Figure 12.1) from February 1990 to December 2009 are presented in Table 12.1. Samples were taken for the express purpose of determining compliance with the state instantaneous standard limiting maximum temperature to 20 °C and 21 °C for natural and stockable trout waters, respectively. Figure 12.2 shows the average monthly temperature for all stations. It is evident from Figure 12.2 that the water temperature in these streams follows a clear seasonal trend. Highest water temperatures are observed during July and lowest are observed during January.

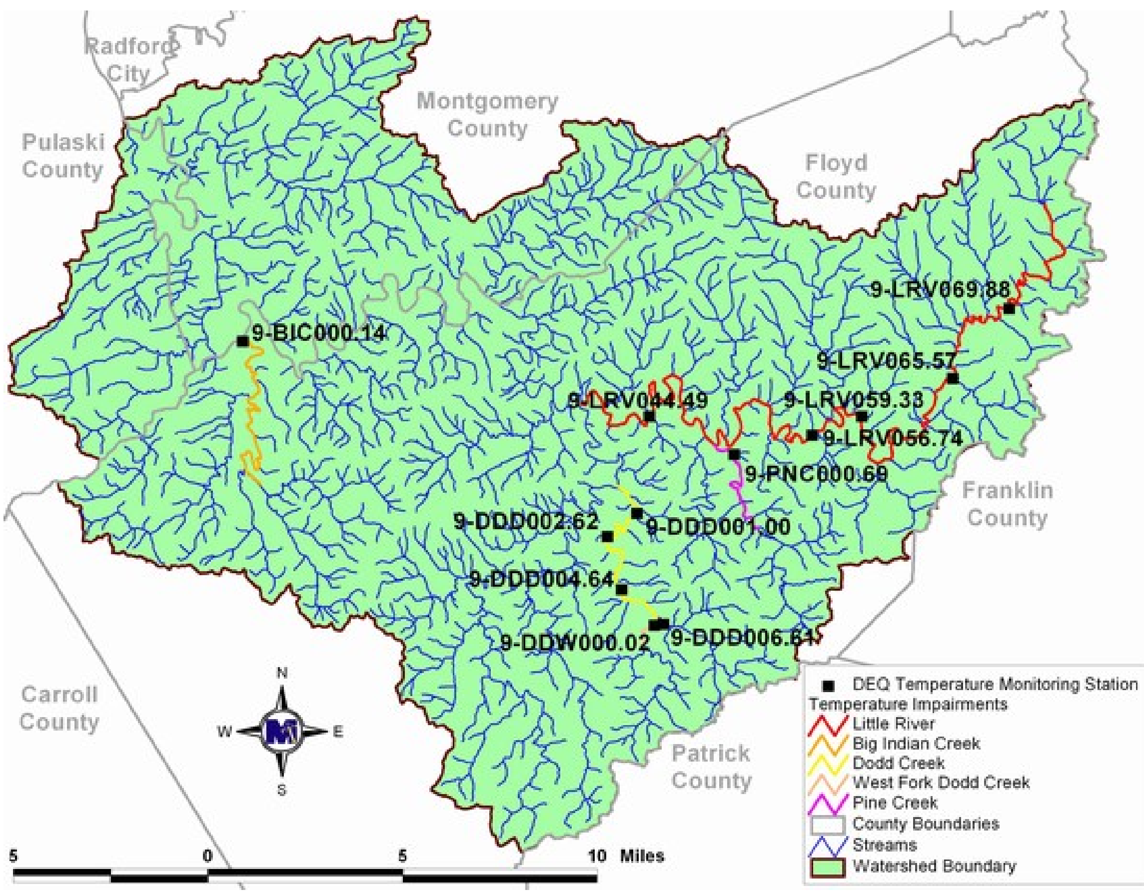

Figure 12.1 Location of VADEQ temperature water quality monitoring stations in the Little River watershed.

Table 12.1 Summary of temperature (°C) data collected by VADEQ from February 1990 to December 2009.

Stream	Station	Samling Dates	Count	Minimum	Maximum	Mean	Median	Standard Deviation	Violation[1] %
Pine Creek	9-PNC000.69	08/2003 - 06/2005	11	0.6	21.3	11.7	12.4	7.5	18.2%[1]
Big Indian Creek	9-BIC000.14	07/2001 - 11/2008	23	0.1	23.9	11.1	10.4	7.5	13.0%[2]
Dodd Creek	9-DDD001.00	08/2005 - 12/2009	27	0.0	22.1	12.0	10.4	6.9	11.1%[2]
Dodd Creek	9-DDD002.62	02/1990 - 12/2009	42	0.5	24.5	12.3	11.5	6.6	11.9%[2]
Dodd Creek	9-DDD004.62	02/1990 - 12/2006	49	1.8	24.5	12.9	12.7	6.4	10.2%[2]
Dodd Creek	9-DDD006.61	03/2003 - 05/2004	4	11.0	18.5	13.7	12.7	3.4	0.0%[2]
W. F. Dodd Creek	9-DDW000.02	01/2007 - 12/2009	18	0.0	22.3	12.4	12.0	6.7	11.1%[1]
Little River	9-LRV044.49	08/2003 - 06/2005	12	2.2	23.3	12.1	11.9	7.9	16.7%[1]
Little River	9-LRV056.74	08/2003 - 10/2009	14	0.3	21.4	11.4	12.2	7.4	14.3%[1]
Little River	9-LRV059.33	11/1996 - 05/2000	16	1.9	25.7	13.1	12.5	7.1	18.8%[1]
Little River	9-LRV065.57	08/2003 - 12/2009	20	0.7	20.4	11.1	10.8	6.2	10.0%[1]
Little River	9-LRV069.88	08/2003 - 06/2005	11	0.4	20.0	10.0	11.8	7.2	0.0%[1]

[1] Based on the natural trout waters maximum temperature standard of 20 °C.

[2] Based on the stockable trout waters maximum temperature standard of 21 °C.

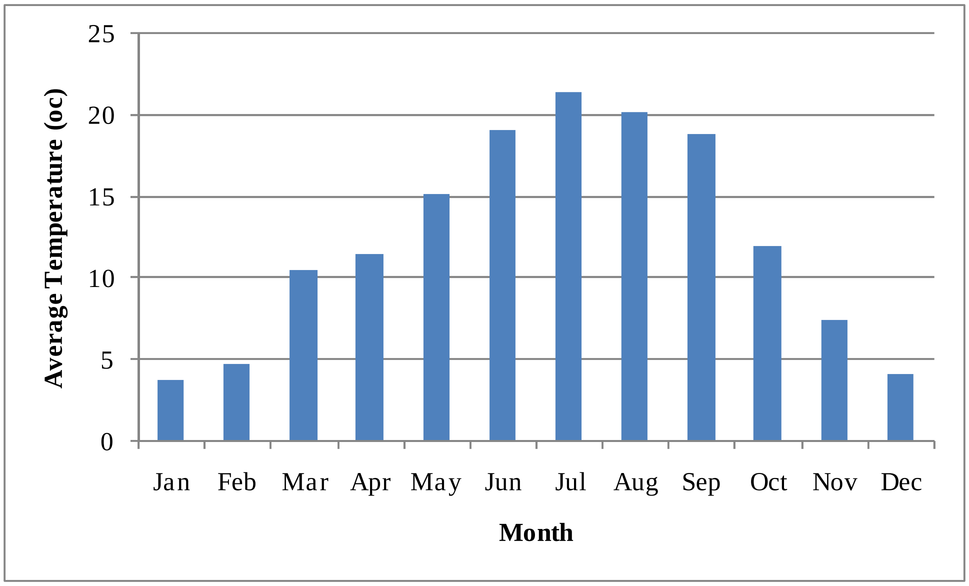

Figure 12.2 Monthly average temperature in the Little River and Tributaries.

12.5 Model Simulation

The USGS Stream Segment Temperature Model (SSTEMP) Version 2.0 (Bartholow, 2002) was used in this project. The model predicts the minimum, maximum, and average temperatures for a single segment for any given day of the year. The model simulates different heat flux processes including convection, conduction, evaporation, short and long wave radiation, and radiation back from the water. The model requires various inputs describing hydrology, channel geometry, and meteorology in addition to optional shade parameters.

For the hydrology component, SSTEMP requires segment inflow and outflow rates and temperatures. Channel geometry is described using segment length, highest and lowest elevations, Manning's n, and channel width-flow relationship. Meteorology is described using air temperature, relative humidity, wind speed, ground temperature, possible sun, and thermal gradient that described thermal input from streambed to water. Shade parameters include average azimuth of segment, topographic altitude, and vegetation parameters. Topographic altitude is a measure of the average incline to the horizon from the center of the stream when looking perpendicular to flow direction (Bartholow, 2002). Vegetation parameters describe the height of vegetation, the crown width, distance between vegetation and edge of stream, and vegetation density. All four vegetation parameters may be varied by stream side.

12.6 Sensitivity Analysis

Sensitivity of the model to changes in input variables was assessed. Base values used in the analysis are shown in Table 12.2. Table 12.2 also shows the percentage change in average temperature due to changes of -10% and +10% in input variables. Resulting impact due to changes in input variables on average temperature are shown in Figure 12.3. The horizontal axis represents the percentage change in the mean simulated temperature due to a change of -10% and +10% in the variables shown on the vertical axis. Black bars represent responses to the -10% change in parameters while gray bars represent responses to the +10% change in the input variables. It is evident from the graph that air temperature has the most impact on resulting average temperature in the stream. It is evident from Table 12.2 and Figure 12.3 that while an increase in some parameters causes an increase in temperature (e.g. air temperature), an increase in other parameters such as total shade results in lower stream water temperature.

Table 12.2 Average temperature sensitivity analysis

Input Variable	Base Value	Change in Average Temperature Resulting from	
		-10%	+10%
Air Temperature (^oC)	20	-5.7%	6.2%
Relative Humidity (%)	80	-2.7%	2.8%
Inflow (cms)	1	-1.6%	1.6%
Accretion Temperature (^oC)	10	-1.6%	1.6%
Width's A Term (s/m^2)	12	-1.4%	1.4%
Inflow Temperature (^oC)	20	-1.2%	1.2%
Possible Sun (%)	80	-0.7%	0.8%
B Term	0.2	-0.1%	0.2%
Ground Temperature (^oC)	10	-0.1%	0.2%
Vegetation Offset (m)	1	-0.1%	0.1%
Manning's n	0.035	0.0%	0.0%
Ground Reflectivity (%)	25	0.0%	0.1%
Dust Coefficient	5	0.1%	0.0%
Thermal Gradient ($j/m^2/s/C$)	1.65	0.1%	-0.1%
Wind Speed (km/hr)	5	0.2%	-0.1%
Vegetation Crown (m)	5	0.2%	-0.2%
Vegetation Height (m)	10	0.4%	-0.3%
Vegetation Density (%)	50	0.6%	-0.5%
Total Shade %	35	0.8%	-0.8%
Outflow (cms)	2	2.5%	-2.2%

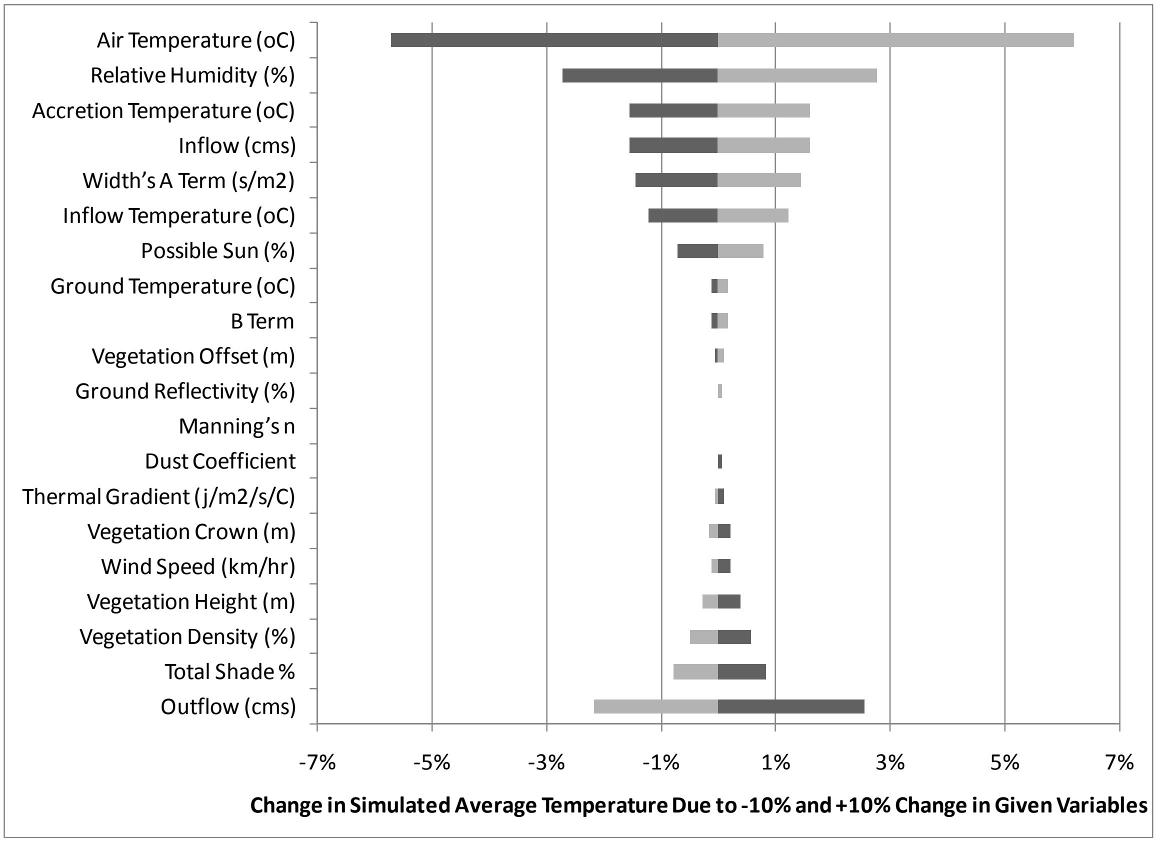

Figure 12.3 Average temperature sensitivity analysis

12.7 Model Calibration

The temperature model was calibrated for average July and August conditions. These two months were selected since they represent the hottest two months of the year. Temperature data from eight VADEQ stations were used in the calibration. The target observed temperature was the average July-August samples. Since SSTEMP runs on a one day time period, the date representing the middle of the range of the sampling dates was used in the model.

Flow for the different drainage areas was estimated using simple regression as a function of the ratio of drainage area of segment to drainage area at USGS gage and the average July/August flow at USGS station 03170000. Air temperature was taken to be the average air temperature for the July/August period and adjusted for elevation difference from the Floyd NCDC station. Relative humidity for the July/August period was obtained for the Roanoke Regional Airport and adjusted for elevation difference with the study area. Geometry variables were obtained from GIS with the exception of the width's A and B terms. The B term was fixed at the default value and the A term was used as a calibration parameter due to the lack of flow-width measurements. Accretion and ground temperatures were estimated as the average annual air temperature. Possible sun was set to 90% which is the default in SSTEMP. Dust coefficient and ground reflectivity were set to 5 and 25%, respectively.

A GIS approach was utilized to estimate the portion of the stream side with tree canopy. A buffer was created inside GIS around the stream segment and intersected with the polygons representing wooded areas. The portion of the stream buffer intersecting wooded area divided by the entire length of the stream was used to estimate vegetation density. This approach was conducted on both sides of the stream allowing varying stream shading on either side of the stream. Vegetation height and canopy width were set to 8m and 5m, respectively. Details of input variables are given in Table 12.3.

Table 12.3 Temperature calibration input parameter values.

Parameter	Upper Little River	Middle Little River	Lower Little River	W.F. Dodd Creek	Pine Creek	Upper Dodd Creek	Lower Dodd Creek	Big Indian Creek
Inflow (cms)	0	0.938	1.81	0	0	0.358	0.463	0.301
Inflow Temperature (°C)	20	19.00	20.28	20	10	19.96	20.45	17.02
Outflow (cms)	0.938	1.81	2.49	0.176	0.269	0.463	0.544	0.783
Accretion Temperature (°C)	11.167	11.167	11.167	11.167	11.167	11.167	11.167	11.167
Latitude (radians)	0.646	0.646	0.646	0.646	0.646	0.646	0.646	0.646
Dam at Head Segment	Not checked	Not checked	Not checked	Not checked	Not checked	Not checked	Not checked	Not checked
Segment Length (km)	22.61	17.55	13.853	10.4	12.05	4.035	6.087	12.587
Upstream Elevation (m)	778	694	663	881	758	700	682	666
Downstream Elevation (m)	694	663	644	700	663	682	657	579
Width's A Term (s/m^2)	8	10	14	8	7	9	8	8
B Term	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Manning's n	0.035	0.035	0.035	0.035	0.035	0.035	.035	0.035
Air Temperature (°C)	21.586	21.96	22.128	21.229	21.754	21.882	22.02	22.07
Maximum Air Temperature (°C)	Not checked	Not checked	Not checked	Not checked	Not checked	Not checked	Not checked	Not checked
Relative Humidity (%)	84	84	84	84	84	84	84	84
Wind Speed (km/hr)	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
Ground Temperature (°C)	11.167	11.167	11.167	11.167	11.167	11.167	11.167	11.167
Thermal Gradient (j/m^2/s/C)	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65
Possible Sun (%)	90	90	90	90	90	90	90	90
Dust Coefficient	5	5	5	5	5	5	5	5
Ground Reflectivity (%)	25	25	25	25	25	25	25	25
Azimuth (radians)	0.785	0.9	1	0.4	0.2	0.45	0.7	0.2
Topographic Altitude (radians)	0.3 (E) 0.25 (W)	0.25 (E) 0.2 (W)	0.15 (E) 0.15 (W)	0.3 (E) 0.25 (W)	0.1 (E) 0.15 (W)	0.3 (E) 0.25(W)	0.4 (E) 0.35 (W)	0.5 (E) 0.5 (W)
Vegetation Height (m)	8 (E) 8 (W)	8 (E) 8 (W)	8 (E) 8 (W)	8 (E) 8 (W)	8 (E) 8 (W)	8 (E) 8 (W)	8 (E) 8(W)	8 (E) 8 (W)
Vegetation Crown (m)	5 (E) 5(W)	5 (E) 5 (W)	5 (E) 5 (W)	5 (E) 5 (W)	5 (E) 5 (W)	5 (E) 5 (W)	5 (E) 5 (W)	5 (E) 5 (W)
Vegetation Offset (m)	1 (E) 1 (W)	1 (E) 1 (W)	1 (E) 1 (W)	1 (E) 1 (W)	1 (E) 1 (W)	1 (E) 1 (W)	1 (E) 1 (W)	1 (E) 1 (W)
Vegetation Density (%)	47 (E) 38 (W)	31 (E) 54 (W)	36 (E) 49 (W)	47 (E) 38 (W)	43 (E) 42 (W)	40 (E) 45 (W)	47 (E) 38 (W)	40 (E) 45 (W)

(E) and (W) refer to east and west sides of the stream, respectively.

The results of mean temperature calibration are given in Table 12.4. The table also shows the simulated minimum and maximum temperatures. Graphic representation of the results is given in Figure 12.4 that shows simulated and observed mean temperatures. By examining the percentage error and the graphical results, it can be seen that the model simulated the average temperature fairly reasonably.

Table 12.4 Temperature calibration results.

Segment	No. of samples	Range of Sampling Dates	Mean Observed Temp. (oC)	Mean Simulated Temp. (oC)	% Error	Maximum Simulated Temp. (oC)	Minimum Simulated Temp. (oC)
Upper Little River	3	8/2 - 8/12	18.95	19.00	0.3%	22.33	15.66
Middle Little River	2	8/2 - 8/12	20.10	20.28	0.9%	23.33	17.22
Lower Little River	2	8/2 - 8/12	21.6	21.57	-0.1%	24.68	18.46
Pine Creek	2	8/2 - 8/12	19.55	19.52	0.1%	23.66	15.44
W. F. Dodd Creek	3	7/1 - 8/5	20.17	19.99	-0.9%	24.25	15.73
Upper Dodd Creek	11	7/8 - 8/14	21.15	20.48	-3.3%	24.34	16.62
Lower Dodd Creek	5	7/1 - 8/14	20.54	21.29	3.5%	24.63	17.95
Big Indian Creek	4	7/1 - 7/18	21.76	20.96	-3.8%	24.64	17.25

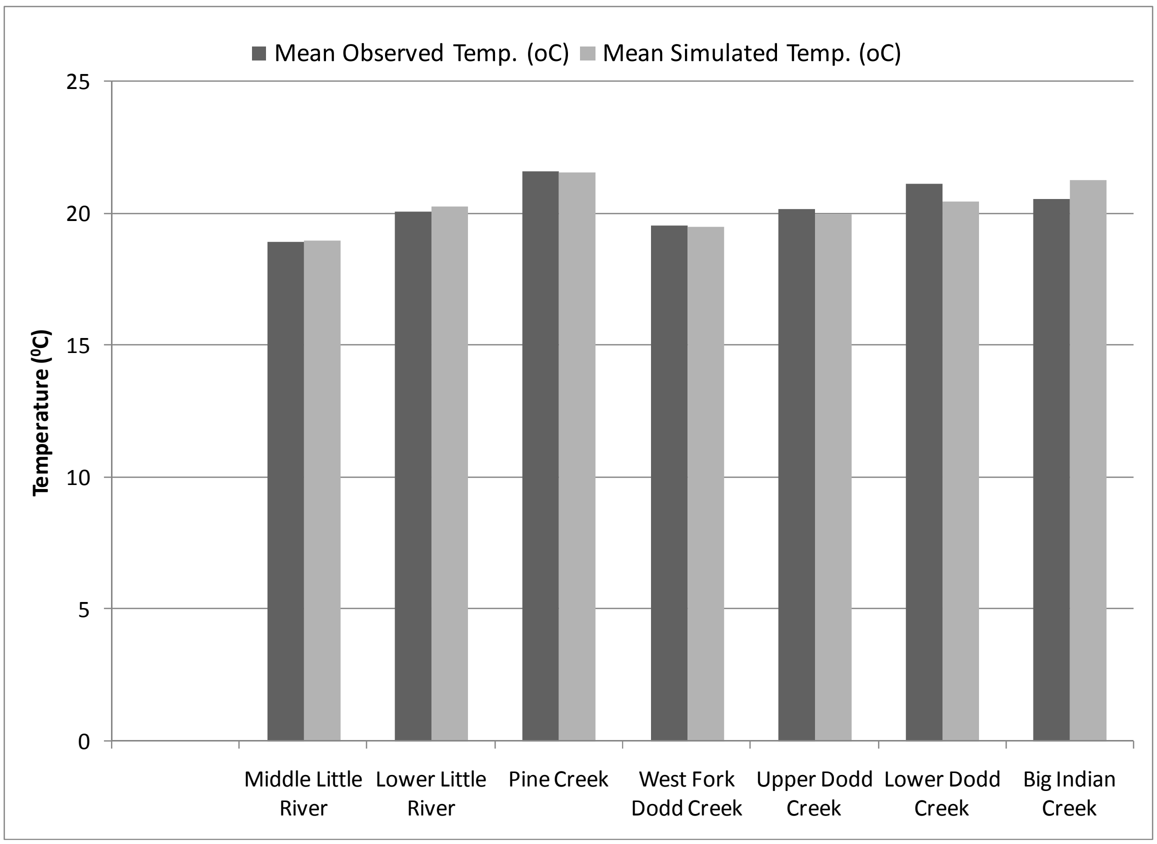

Figure 12.4 Observed and simulated mean temperatures for the Little River and Tributaries.

12.8 Load Allocation

Using the calibrated model, allocations were run for the eight impairments. An implicit margin of safety (MOS) was implemented in this study. This was achieved by using July and August average flows as input to the model instead of using annual average flow. July/August average flows are lower than the average annual flow and using the summer flow is considered conservative and protective of water quality. In addition to using the summer flow, the simulation date in the model was set, during the allocation stage, to July 20 which is the day with the hottest average daily temperature in the year.

The percent shade was increased in the model until the water quality standards were met. Upland segments were allocated first and the allocated output from those segments was then used during the allocation of downstream segments. Allocation was conducted until all eight impaired segments met the water quality standards. Tables 12.5 through 12.12 show the mean heat flux (j/m^2/s), existing maximum temperature for existing and allocated conditions for multiple scenarios in addition to the final allocation scenario.

Table 12.5 Existing and allocation scenarios for Upper Little River.

Upper Little River	Effective Shade (%)	Maximum Simulated Temperature (^{o}C)	Mean Heat Flux at Outflow (j/m^2/s)
Existing	33.4	23.21	202.96
Scenario 1	40	22.7	197.12
Scenario 2	50	21.91	188.17
Scenario 3	60	21.11	179.1
Scenario 4	70	20.3	169.91
Scenario 5 (final allocation)	74	19.98	166.21

Table 12.6 Existing and allocation scenarios for Middle Little River.

Middle Little River	Effective Shade (%)	Maximum Simulated Temperature (°C)	Mean Heat Flux at Outflow ($j/m^2/s$)
Existing	22.07	24.13	196.51
Scenario 1	30	23.58	189.69
Scenario 2	40	22.87	180.91
Scenario 3	50	22.16	171.96
Scenario 4	60	21.44	162.83
Scenario 5	70	20.72	153.52
Scenario 6 (final allocation)	80	19.99	144.02

Table 12.7 Existing and allocation scenarios for Lower Little River.

Lower Little River	Effective Shade (%)	Maximum Simulated Temperature (°C)	Mean Heat Flux at Outflow ($j/m^2/s$)
Existing	14.7	25.22	174.38
Scenario 1	20	24.86	169.77
Scenario 2	30	24.19	160.92
Scenario 3	40	23.51	151.87
Scenario 4	50	22.83	142.64
Scenario 5	60	22.14	133.21
Scenario 6	70	21.45	123.58
Scenario 7	80	20.76	113.75
Scenario 8	90	20.06	103.73
Scenario 9 (final allocation)	91	19.99	102.72

Table 12.8 Existing and allocation scenarios for Pine Creek.

Pine Creek	Effective Shade (%)	Maximum Simulated Temperature (°C)	Mean Heat Flux at Outflow ($j/m^2/s$)
Existing	37.96	24.47	172.45
Scenario 1	40	24.3	171.08
Scenario 2	50	23.41	163.49
Scenario 3	60	22.5	155.79
Scenario 4	70	21.57	147.57
Scenario 5	80	20.62	140.06
Scenario 6 (final allocation)	86.5	19.99	134.85

Table 12.9 Existing and allocation scenarios for West Fork Dodd Creek.

W. F. Dodd Creek	Effective Shade (%)	Maximum Simulated Temperature (°C)	Mean Heat Flux at Outflow (j/m²/s)
Existing	39.47	24.95	130.49
Scenario 1	50	23.98	124.15
Scenario 2	60	23.03	118.03
Scenario 3	70	22.04	111.81
Scenario 4	80	21.03	105.5
Scenario 5 (final allocation)	90	19.98	99.08

Table 12.10 Existing and allocation scenarios for Upper Dodd Creek.

Upper Dodd Creek	Effective Shade (%)	Maximum Simulated Temperature (°C)	Mean Heat Flux at Outflow (j/m²/s)
Existing	33.26	24.6	187.11
Scenario 1	40	24.08	178.84
Scenario 2	50	23.29	166.43
Scenario 3	60	22.49	153.84
Scenario 4	70	21.68	141.08
Scenario 5 (final allocation)	78.6	20.99	129.97

Table 12.11 Existing and allocation scenarios for Lower Dodd Creek.

Lower Dodd Creek	Effective Shade (%)	Maximum Simulated Temperature (°C)	Mean Heat Flux at Outflow (j/m²/s)
Existing	35.26	25.02	138.71
Scenario 1	40	24.67	133.8
Scenario 2	50	23.91	123.32
Scenario 3	60	23.15	112.66
Scenario 4	70	22.38	101.8
Scenario 5	80	21.61	90.77
Scenario 6 (final allocation)	88	20.98	81.81

Table 12.12 Existing and allocation scenarios for Big Indian Creek.

Big Indian Creek	Effective Shade (%)	Maximum Simulated Temperature (°C)	Mean Heat Flux at Outflow (j/m²/s)
Existing	34.93	25.33	151.66
Scenario 1	40	24.91	148.59
Scenario 2	50	24.06	142.43
Scenario 3	60	23.2	136.16
Scenario 4	70	22.32	129.77
Scenario 5	80	21.42	123.25
Scenario 6 (final allocation)	84.6	20.99	120.21

Table 12.13 shows the temperature TMDL equations for all impairments. Since no point sources exist in the watershed with known elevated temperatures, the only component in the waste load allocation (WLA) is the future growth component. Future growth was set as one percent of the TMDL. The difference between the TMDL and the WLA is considered the load allocation (LA).

Table 12.13 Daily temperature total maximum daily load within the Little River watershed in Joules/m²/s.

Impairment	WLA	LA	MOS	TMDL
Little River VAW-N19R_LRV01A00	1.66	164.55	*Implicit*	166.21
Little River VAW-N19R_LRV02A00	1.44	142.58		144.02
Little River VAW-N19R_LRV03A00	1.03	101.69		102.72
Pine Creek VAW-N19R_PNC01A06	1.35	133.5		134.85
West Fork Dodd Creek VAW-N20R_DDW01A02	0.99	98.09		99.08
Dodd Creek VAW-N20R_DDD01A00	1.3	128.67		129.97
Dodd Creek VAW-N20R_DDD02A00	0.82	80.99		81.81
Big Indian Creek VAW-N21R_BIC01A02	1.2	119.01		120.21

13. TMDL IMPLEMENTATION AND REASONABLE ASSURANCE

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels from both point and nonpoint sources. EPA requires that there is reasonable assurance that TMDLs can be implemented. TMDLs represent an attempt to quantify the pollutant load that might be present in a waterbody and still ensure attainment and maintenance of water quality standards. The Commonwealth intends to use existing programs in order to attain water quality goals. Available programmatic options include a combination of regulatory authorities, such as the NPDES and state programs.

The following sections outline the framework used in Virginia to provide reasonable assurance that the required pollutant reductions can be achieved.

13.1 Continuing Planning Process and Water Quality Management Planning

As part of the Continuing Planning Process, VADEQ staff will present both EPA-approved TMDLs and TMDL implementation plans to the State Water Control Board (SWCB) for inclusion in the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e) and Virginia's Public Participation Guidelines for Water Quality Management Planning.

VADEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards. This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia. SWCB actions relating to water quality management planning are described in the public participation guidelines referenced above and can be found on the VADEQ web site under www.deq.state.va.us/export/sites/default/tmdl/pdf/ppp.pdf.

13.2 Staged Implementation

In general, Virginia intends for the required control actions, including Best Management Practices (BMPs), to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. The iterative implementation of pollution control actions in the watershed has several benefits:

1. It enables tracking of water quality improvements following implementation through follow-up stream monitoring;
2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;
3. It provides a mechanism for developing public support through periodic updates on implementation levels and water quality improvements;
4. It helps ensure that the most cost effective practices are implemented first; and
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

13.3 Implementation of Waste Load Allocations

Federal regulations require that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the assumptions and requirements of any applicable TMDL WLA (40 CFR §122.44 (d)(1)(vii)(B)). All such permits should be submitted to EPA for review.

13.3.1 Stormwater

VADEQ and VADCR coordinate separate state permitting programs that regulate the management of pollutants carried by stormwater runoff. VADEQ regulates stormwater discharges associated with industrial activities through its VPDES program, while VADCR regulates stormwater discharges from construction sites, and from municipal separate storm sewer systems (MS4s) through the VSMP program. Stormwater discharges from coal mining operations are permitted through NPDES permits by the Department of Mines, Minerals and Energy (DMME). As with non-stormwater permits, all new or revised stormwater permits must be consistent with the assumptions and requirements of any applicable TMDL WLA. If a WLA is based on conditions specified in existing permits, and the permit conditions are being met, no additional actions may be needed. If a WLA is based on reduced pollutant loads, additional pollutant control actions will need to be implemented.

The Virginia Erosion and Sediment Control and Virginia Stormwater Management Programs – administered by the Department of Conservation and Recreation and delegated to local jurisdictions – provides the framework for implementing sediment reduction BMPs throughout localities. More information regarding these programs can be found at http://www.dcr.virginia.gov/soil_&_water/e&s.shtml.

13.3.2 TMDL Modifications for New or Expanding Discharges

Permits issued for facilities with wasteload allocations developed as part of a Total Maximum Daily Load (TMDL) must be consistent with the assumptions and requirements of these wasteload allocations (WLA), as per EPA regulations. In cases where a proposed permit modification is affected by a TMDL WLA, permit and TMDL staff must coordinate to ensure that new or expanding discharges meet this requirement. In 2005, VADEQ issued guidance memorandum 05-2011 describing the available options and the process that should be followed under those circumstances, including public participation, EPA approval, State Water Control Board actions, and coordination between permit and TMDL staff. The guidance memorandum is available on VADEQ's web site at www.deq.virginia.gov/waterguidance/.

13.4 Implementation of Load Allocations

The TMDL program does not impart new implementation authorities. Therefore, the Commonwealth intends to use existing programs to the fullest extent in order to attain its water quality goals. The measures for non point source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the TMDL implementation plan.

13.4.1 Implementation Plan Development

For the implementation of the TMDL's LA component, a TMDL implementation plan is developed that addresses at a minimum the requirements specified in the Code of Virginia, Section 62.1-44.19:7. State law directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters". The implementation plan "shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments". EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process". The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

In order to qualify for other funding sources, such as EPA's Section 319 grants, additional plan requirements may need to be met. The detailed process for developing an implementation plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003 (VADCR & VADEQ, 2003). It is available upon request from the VADEQ and VADCR TMDL project staff or at www.deq.virginia.gov/tmdl/implans/ipguide.pdf.

Watershed stakeholders have opportunities to provide input and to participate in the development of the TMDL implementation plan. Regional and local offices of VADEQ, VADCR, and other cooperating agencies are technical resources to assist in this endeavor.

With successful completion of implementation plans, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation.

13.4.2 Staged Implementation Scenarios

The purpose of the staged implementation scenarios is to identify one or more combinations of implementation actions that result in the reduction of controllable sources to the maximum extent practicable using cost-effective, reasonable BMPs for nonpoint source control.

Among the most efficient bacterial BMPs for both urban and rural watersheds are stream side fencing for cattle farms, pet waste clean-up programs, and government or grant programs available to homeowners with failing septic systems and installation of treatment systems for homeowners currently using straight pipes. Among the most efficient sediment BMPs for both urban and rural watersheds are infiltration and retention basins, riparian buffer zones, grassed waterways, streambank protection and stabilization, and wetland development or enhancement.

As for temperature, riparian buffers with vegetated areas around the streams provide the extra shading needed to bring down water temperatures in the streams to acceptable levels. In the case of Little River, grass-only buffers may not be suitable because while they represent a BMP that helps with reducing the influx of bacteria and sediment to streams, they provide little in terms of shading.

Actions identified during TMDL implementation plan development that go beyond what can be considered cost-effective and reasonable will only be included as implementation actions, if there are reasonable grounds for assuming that these actions will in fact be implemented.

If water quality standards are not met upon implementation of all cost-effective and reasonable BMPs, a Use Attainability Analysis (UAA) may need to be initiated since Virginia's water quality standards allow for changes to use designations if existing water quality standards cannot be attained by implementing effluent limits required under §301b and §306 of Clean Water Act, and by implementing cost effective and reasonable BMPs for nonpoint source control. Additional information on UAAs is presented in Section 13.6.

13.4.3 Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality downstream in the Little River watershed. The water quality in the Little River as impacted by sediment and bacteria will be improved once the previously developed bacteria TMDLs for Mill and Dodd Creeks are implemented.

13.4.4 Implementation Funding Sources

The implementation of pollutant reductions from non-regulated nonpoint sources relies heavily on incentive-based programs. Therefore, the identification of funding sources for non-regulated implementation activities is a key to success. Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the *Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans*. The *TMDL Implementation Plan Guidance Manual* contains information on a variety of funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

Some of the major potential sources of funding for non-regulated implementation actions may include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program (also available for permitted activities), the Virginia Water Quality Improvement Fund (available for both point and nonpoint source pollution), tax credits and landowner contributions.

With additional appropriations for the Water Quality Improvement Fund during the last two legislative sessions, the Fund has become a significant funding source for agricultural BMPs and wastewater treatment plants. Additionally, funding is being made available to address urban and residential water quality problems. Information on WQIF projects and allocations can be found at www.deq.virginia.gov/bay/wqif.html and at www.dcr.virginia.gov/soil_&_water/wqia.shtml.

13.5 Follow-Up Monitoring

Following the development of the TMDL, VADEQ will make every effort to continue to monitor the impaired streams in accordance with its ambient and biological monitoring programs. VADEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with *DEQ Guidance Memo No. 03-*

2004 (www.deq.virginia.gov/waterguidance/pdf/032004.pdf) (VADEQ, 2003b), during periods of reduced resources, monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or where deemed necessary by the regional office or TMDL staff, as a new special study. Since there may be a lag time of one-to-several years before any improvement in the benthic community will be evident, follow-up biological monitoring may not have to occur in the fiscal year immediately following the implementation of control measures. The details of the follow-up ambient and biological monitoring will be outlined in the Annual Water Monitoring Plan prepared by each VADEQ Regional Office. Impact of some measures such as forested riparian buffers on reducing temperature may take several years to fully influence water quality conditions.

The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the VADEQ staff, the Implementation Plan Steering Committee and local stakeholders. Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station. At a minimum, the monitoring station must be representative of the original impaired segment.

VADEQ staff, the Implementation Plan Steering Committee and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants ("water quality milestones" as established in the IP), the effectiveness of the TMDL in attaining and maintaining water quality standards, and the success of implementation efforts. Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

In some cases, watersheds will require monitoring above and beyond what is included in VADEQ's standard monitoring plans. Ancillary monitoring by citizens' or watershed groups, local government, or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with VADEQ monitoring data. In instances where citizens' monitoring data are not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request of the monitoring managers in each regional office an increase in the number of stations or to monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bimonthly single station monitoring will be contingent on staff resources and available laboratory budget. More information on VADEQ's citizen monitoring in Virginia and QA/QC guidelines is available at www.deq.virginia.gov/cmonitor/.

To demonstrate that the watershed is meeting water quality standards in watersheds where corrective actions have taken place, VADEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, temperature, etc) is bimonthly monitoring for two consecutive years. For biological monitoring, the minimum requirement is two consecutive samples (one in the spring and one in the fall) in a one-year period.

13.6 Attainability of Designated Uses

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use. In order for a stream to be assigned a new designated use, or a subcategory of a use, the current designated use must be removed. To remove a designated use, the state must demonstrate that the use is not an existing use, and that downstream uses are protected. Such uses will be attained by implementing effluent limits required under §301b and §306 of Clean Water Act and by implementing cost-effective and reasonable best management practices for nonpoint source control (9 VAC 25-260-10 paragraph I).

The state must also demonstrate that attaining the designated use is not feasible because:

1. Naturally occurring pollutant concentration prevents the attainment of the use;

2. Natural, ephemeral, intermittent or low flow conditions prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation;

3. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place;

4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate the modification in such a way that would result in the attainment of the use;

5. Physical conditions related to natural features of the water body, such as the lack of proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life use protection; or

6. Controls more stringent than those required by §301b and §306 of the Clean Water Act would result in substantial and widespread economic and social impact.

This and other information is collected through a special study called a UAA. All site-specific criteria or designated use changes must be adopted by the SWCB as amendments to the water quality standards regulations. During the regulatory process, watershed stakeholders and other interested citizens, as well as the EPA, will be able to provide comment. Additional information can be obtained at www.deq.virginia.gov/wqs/designated.html.

The process to address potentially unattainable reductions based on the above is as follows:

As a first step, measures targeted at the controllable, anthropogenic sources identified in the TMDL's staged implementation scenarios will be implemented. The expectation is that all controllable sources would be reduced to the maximum extent possible using the implementation approaches described above. VADEQ will continue to monitor biological health and water quality in the stream during and subsequent to the implementation of these measures to determine if the water quality standard is attained. This effort will also help to evaluate if the modeling assumptions were correct. In the best-case scenario, water quality goals will be met and the stream's uses fully restored using effluent controls and BMPs. If, however, water quality standards are not being met, and no additional effluent controls and BMPs can be identified, a UAA would then be initiated with the goal of re-designating the stream for a more appropriate use or subcategory of a use.

A 2006 amendment to the Code of Virginia under 62.1-44.19:7E provides an opportunity for aggrieved parties in the TMDL process to present to the State Water Control Board reasonable grounds indicating that the attainment of the designated use for a water is not feasible. The Board may then allow the aggrieved party to conduct a use attainability analysis according to the criteria listed above and a schedule established by the Board. The amendment further states that “If applicable, the schedule shall also address whether TMDL development or implementation for the water shall be delayed”.

14. IMPLEMENTATION

This chapter will be populated once the TMDL IP is completed

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15. PUBLIC PARTICIPATION

Public participation during TMDL development for the Little River watershed was encouraged; a summary of the meetings is presented in Table 15.1. The first public meeting took place on September 28, 2010 at Sinkland Farms near Riner, VA. The meeting was publicized by placing notices in the Virginia Register, signs in the watershed, and emailing notices to local stakeholders and representatives. A total of 23 people attended the event (including the exhibitors). A variety of informational booths were set up for attendees to peruse at their own pace. The Skyline Soil and Water District displayed information about ongoing best management practice installation in the Mill Creek and Dodd Creek watersheds as well as general information about water quality and stewardship. MapTech, Inc. shared technical information about the Little River TMDLs including animal number estimates in the watershed. DEQ displayed maps of the watershed showing monitoring stations and impairments, a "bug tub" with benthic macroinvertebrates common in the watershed, water quality measurement tools, and data. The National Committee for the New River presented information about citizen monitoring and other programs throughout the entire New River watershed. Snacks, handouts and a continuous PowerPoint presentation were available to attendees.

The final public meeting …..

Table 15.1 Public participation during TMDL development for the Little River study area.

Date	Location	Number of Attendees	Type
9/28/2010	Sinkland Farms near Riner, VA	23	First TMDL Public
2/?/2011	?	?	Final TMDL Public First IP Public

Public participation during the implementation plan development process includes the formation of stakeholders' committees, with committee and public meetings. Public participation is critical to promote reasonable assurances that the implementation activities will occur. Stakeholder committees will have the express purpose of formulating the TMDL Implementation Plan. The committees consist of, but are not limited to, representatives from VADEQ, VADCR, and local governments. These committees have the responsibility for identifying corrective actions that are founded in practicality, establishing a time line to insure expeditious implementation, and setting measurable goals and milestones for attaining water quality standards.

REFERENCES

American Veterinary Medical Association – Center for Information Management. 1997 U.S. Pet Ownership and Demographics Sourcebook.

Armour, C.L., D.A. Duff and W. Elmore. 1991. AFS Position Statement. Fisheries, Jan/Feb 1991, p. 7-11.

ASAE Standards, 45th Edition. 1998. D384.1 DEC93. Manure Production and Characteristics. St. Joseph, Mich.: ASAE.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, Benthic macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water, Washington, D.C.

Bartholow, J. 2002. Stream Segment Temperature Model (SSTEMP), Version 2.0, User's Manual. United States Geological Survey, Fort Collins Science Center Online, Fort Collins, CO (http://www.fort.usgs.gov/products/training/if312.asp).

Bidrowski, T. 2003, Virginia Department of Game and Inland Fisheries. Personal telecommunication, 01/29/03.

Bidrowski, T. 2004. Virginia Department of Game and Inland Fisheries. Personal telecommunication. July 16, 2004 and August 9, 2004.

BSE. 2003. Benthic TMDL for Stroubles Creek in Montgomery County, Virginia. Department of Biological Systems Engineering, Virginia Tech.

Burton, J. and J. Gerritsen, 2003. A Stream Condition Index for Virginia Non-coastal Streams. Tetra Tech, Inc. Owings Mills, Maryland.

Clary, W.P. and B.F. Webster. 1989. Managing grazing of riparian areas in the Intermountain Region. USDA, Forest Service, Intermountain Research Station, General Technical Report INT-263, Ogden, UT.

Costanzo, G. 2003, Virginia Department of Game and Inland Fisheries. Personal telecommunication, 01/29/03.

England, C.B. 1970. Land Capability: A Hydrologic Response Unit in Agricultural Watersheds. Agricultural Research Service, USDA, ARS: 41-172.

Evans, Barry M., S. A. Sheeder, K. J. Corradini, and W. W. Brown. 2001. AVGWLF version 3.2 Users Guide. Environmental Resources Research Institute, Pennsylvania State University and Pennsylvania Department of Environmental Protection, Bureau of Watershed Conservation.

Farrar, R. 2003. Virginia Department of Game and Inland Fisheries. Personal telecommunication.

Fies, M. 2004. Virginia Department of Game & Inland Fisheries. Personal telecommunication. 08/11/04, 08/12/04, and 08/24/04.

Geldreich, E. E. 1978. Bacterial Populations and Indicator Concepts in Feces, Sewage, Stormwater, and Solid Wastes. In Indicators of Viruses in Water and Food, ed. G. Berg. Ann Arbor, Mich.: Ann Arbor Science Publishers, Inc.

Haith, D.A. and L.L. Shoemaker, 1987. Generalized Watershed Loading Functions for Stream Flow Nutrients. Water Resources Bulletin, 23(3), pp. 471-478.

Haith, D.A., R. Mandel, and R.S. Wu. 1992. GWLF. Generalized Watershed Loading Functions, version 2.0 User's Manual. Department of Agricultural and Biological Engineering, Cornell University, Ithaca, New York.

Kaufman, J.B. and W.C. Krueger. 1984. Livestock impacts on riparian plant communities, and streamside management implications. A review. Journal of Range Management 37(3): 430-437.

Kleene, J. Wesley. 1995, Watershed Nonpoint Source Management System: A Geographic Information System Approach, Ph.D. Dissertation, Virginia Polytechnic Institute and University.

Knox, W. M. 2004. Virginia Department of Game & Inland Fisheries. Personal telecommunication. August 03, 2004, August 05, 2004, and August 25, 2004.

Li, E.A. 1975. A model to define hydrologic response units based on characteristics of the soil-vegetative complex within a drainage basin. M.S. Thesis, Department of Agricultural Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA.

Lloyd, K. 2004. Virginia Department of Environmental Quality. Personal telecommunication. September 28, 2004.

MapTech. 1999. Unpublished source sampling data. Blackwater River TMDL Study.

MapTech. 2002. Modeling Cattle Stream Access. Submitted to: VADCR, in cooperation with Biological Systems Engineering Department, Virginia Tech.

Mayhorn, R. 2005. Buchanan County Bird Club. Personal Communication. 08/17/05.

McDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and Evaluation of Consensus Based Sediment Quality Guidelines For Freshwater Ecosystems. Arch. *Environ. Contam. Toxicol.* 39: 20-31.

Norman, G. 2004. Virginia Department of Game & Inland Fisheries. Personal telecommunication. July 12, 2004.

Norman, G.W. 2003. Virginia Department of Game and Inland Fisheries. Personal telecommunication.

Novotny, V., and G. Chesters. 1981. Handbook of Nonpoint Pollution. Van Nostrand Reinhold, New York, NY.

NRCS. 2010a. SSURGO website. www.ncgc.nrcs.usda.gov/branch/ssb/products/ssurgo/

NRCS. 2010b. Regional Hydraulic Geometry Curves. http://wmc.ar.nrcs.usda.gov/technical/HHSWR/Geomorphic/

Raftovich, R. V. 2004. Atlantic Flyway Breeding Waterfowl Plot Survey: Breeding Pair and Population Size Estimates 2004. U.S. Fish and Wildlife Service. Division of Migratory Bird Management. July 28, 2004.Reneau, R.B., Jr. 2000. Department of Crop and Soil Environmental Sciences, Virginia Tech. Personal communication. January 7, 2000.

Rose, R.K., Cranford, J.A. 1987. Handbook of Virginia Mammals. Final Report, Project No. 567460. VA Dept. Game & Inland Fisheries, Richmond, VA: 121.

Schwab, G. O., R. K. Frevert, T. W. Edminster, and K. K. Barnes. 1981. Soil and Water Conservation Engineering. 3rd ed. New York: John Wiley & Sons.

SCS. 1986. Urban Hydrology for Small Watersheds, USDA Soil Conservation Service, Engineering Division, Technical Release 55.

SERCC. 2010. Southeast Regional Climate Center. www.water.dnr.state.sc.us/climate/sercc

USCB, 1990. *1990 Census*. United States Census Bureau. Washington D.C.

USCB, 2000. *2000 Census*. United States Census Bureau. Washington D.C.

USDI, Bureau of Land Management. 1998. Riparian area management: process for assessing proper functioning conditions. Technical Reference 1737-9, National Applied Science Center, Denver, CO.

USEPA, 2000. Stressor Identification Guidance Document. U.S. Environmental Protection Agency, Office of Water. Washington, D.C. December 2000. EPA 822-B-00-025.

USEPA, 2007. Options for Expressing Daily Loads in TMDLs.

VADCR and VADEQ. 2003. Guidance Manual for Total Maximum Daily Load Implementation Plans. http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf.

VADEQ, 2009. Memorandum, Little River Algae Investigation IR# 2008-W-0370.

VADEQ. 2002. Section 303(d) Water Quality Assessment Integrated Report.

VADEQ. 2003b. Guidance Memo No. 03-2004. Managing Water Monitoring Programs While Under Reduced Resources. Memo from Larry G. Lawson to Regional Directors of the VADEQ. February 10, 2003. Accessible at: http://www.deq.virginia.gov/waterguidance/pdf/032004.pdf

VADEQ. 2004. Section 303(d) Water Quality Assessment Integrated Report.

VADEQ. 2006. Section 303(d) Water Quality Assessment Integrated Report.

VADEQ. 2008. Section 303(d) Water Quality Assessment Integrated Report.

VADEQ. 2003a. Guidance Memo No. 03-2012. HSPF Model Calibration and Verification for Bacteria TMDLs. Memo from Larry G. Lawson to Regional Directors. September 3, 2003. Accessible at:

VASS, 1998. Virginia Agricultural Statistics Bulletin 1997. Virginia Agricultural Statistics Service. Richmond, VA.

VASS, 2002. Virginia Agricultural Statistics Bulletin 2001. Virginia Agricultural Statistics Service. Richmond, VA.

VDGIF. 1999. www.dgif.state.va.us. Virginia Fish and Wildlife Information Service.

Weiskel. P. A., B. L. Howes, and G. R. Heufelder. 1996. Coliform contamination of a coastal embayment: sources and transport pathways. Environ. Sci. Technol. 30:1872-1881.

Wischmeier, W.H. and D.D. Smith. 1978. Predicting Rainfall Erosion Losses – A Guide to Conservation Planning. U.S. Department of Agriculture. Agriculture Handbook No. 537.www.deq.virginia.gov/waterguidance/pdf/032012.pdf

www.deq.virginia.gov/waterguidance/pdf/032012.pdf

Yagow, E. 1999. Unpublished monitoring data. Mountain Run TMDL Study.

Yagow, G., S. Mostaghimi, and T.A. Dillaha. 2002. GWLF model calibration for statewide NPS assessment. Virginia NPS pollutant load assessment methodology for 2002 and 2004 statewide NPS pollutant assessments. January 1 - March 31, 2002 Quarterly Report. Submitted to Virginia Department Conservation and Recreation, Division of Soil and Water Conservation, Richmond, Virginia.

GLOSSARY

303(d). A section of the Clean Water Act of 1972 requiring states to identify and list water bodies that do not meet the states' water quality standards.

Allocations. *That portion of a receiving water's loading capacity attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources. (A wasteload allocation [WLA] is that portion of the loading capacity allocated to an existing or future point source, and a load allocation [LA] is that portion allocated to an existing or future nonpoint source or to natural background levels. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading.)*

Ambient water quality. *Natural concentration of water quality constituents prior to mixing of either point or nonpoint source load of contaminants. Reference ambient concentration is used to indicate the concentration of a chemical that will not cause adverse impact on human health.*

Anthropogenic. *Pertains to the [environmental] influence of human activities.*

Antidegradation Policies*. Policies that are part of each states water quality standards. These policies are designed to protect water quality and provide a method of assessing activities that might affect the integrity of waterbodies.*

Aquatic ecosystem. *Complex of biotic and abiotic components of natural waters. The aquatic ecosystem is an ecological unit that includes the physical characteristics (such as flow or velocity and depth), the biological community of the water column and benthos, and the chemical characteristics such as dissolved solids, dissolved oxygen, and nutrients. Both living and nonliving components of the aquatic ecosystem interact and influence the properties and status of each component.*

Assimilative capacity*. The amount of contaminant load that can be discharged to a specific waterbody without exceeding water quality standards or criteria. Assimilative capacity is used to define the ability of a waterbody to naturally absorb and use a discharged substance without impairing water quality or harming aquatic life.*

Background levels. *Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering or dissolution.*

Bacteria. *Single-celled microorganisms. Bacteria of the coliform group are considered the primary indicators of fecal contamination and are often used to assess water quality.*

Bacterial decomposition. *Breakdown by oxidation, or decay, of organic matter by heterotrophic bacteria. Bacteria use the organic carbon in organic matter as the energy source for cell synthesis.*

Benthic. *Refers to material, especially sediment, at the bottom of an aquatic ecosystem. It can be used to describe the organisms that live on, or in, the bottom of a waterbody.*

Benthic organisms. *Organisms living in, or on, bottom substrates in aquatic ecosystems.*

Best management practices (BMPs). *Methods, measures, or practices determined to be reasonable and cost-effective means for a landowner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.*

Bioassessment. Evaluation of the condition of an ecosystem that uses biological surveys and other direct measurements of the resident biota.

Biochemical Oxygen Demand (BOD). Represents the amount of oxygen consumed by bacteria as they break down organic matter in the water.

Biological Integrity. A water body's ability to support and maintain a balanced, integrated adaptive assemblage of organisms with species composition, diversity, and functional organization comparable to that of similar natural, or non-impacted habitat.

Biometric. (Biological Metric) The study of biological phenomena by measurements and statistics.

Box and whisker plot. A graphical representation of the mean, lower quartile, upper quartile, upper limit, lower limit, and outliers of a data set.

Calibration. *The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.*

Cause. 1. That which produces an effect (a general definition).

2. A stressor or set of stressors that occur at an intensity, duration and frequency of exposure that results in a change in the ecological condition (a SI-specific definition). [2]

Channel. *A natural stream that conveys water; a ditch or channel excavated for the flow of water.*

Chloride. *An atom of chlorine in solution; an ion bearing a single negative charge.*

Clean Water Act (CWA). *The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is Section 303(d), which establishes the TMDL program.*

Concentration. *Amount of a substance or material in a given unit volume of solution; usually measured in milligrams per liter (mg/L) or parts per million (ppm).*

Concentration-based limit. *A limit based on the relative strength of a pollutant in a waste stream, usually expressed in milligrams per liter (mg/L).*

Concentration-response model. A quantitative (usually statistical) model of the relationship between the concentration of a chemical to which a population or community of organisms is exposed and the frequency or magnitude of a biological response. (2)

Conductivity. An indirect measure of the presence of dissolved substances within water.

Confluence. The point at which a river and its tributary flow together.

Contamination. *The act of polluting or making impure; any indication of chemical, sediment, or biological impurities.*

Continuous discharge. *A discharge that occurs without interruption throughout the operating hours of a facility, except for infrequent shutdowns for maintenance, process changes, or other similar activities.*

Conventional pollutants. *As specified under the Clean Water Act, conventional contaminants include suspended solids, coliform bacteria, high biochemical oxygen demand, pH, and oil and grease.*

Conveyance. A measure of the of the water carrying capacity of a channel section. It is directly proportional to the discharge in the channel section.

Cost-share program. *A program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs is paid by the producer(s).*

Cross-sectional area. *Wet area of a waterbody normal to the longitudinal component of the flow.*

Critical condition. *The critical condition can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence.*

Decay. *The gradual decrease in the amount of a given substance in a given system due to various sink processes including chemical and biological transformation, dissipation to other environmental media, or deposition into storage areas.*

Decomposition. *Metabolic breakdown of organic materials; the formation of by-products of decomposition releases energy and simple organic and inorganic compounds. See also* ***Respiration.***

Designated uses. *Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.*

Dilution. *The addition of some quantity of less-concentrated liquid (water) that results in a decrease in the original concentration.*

Direct runoff. *Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.*

Discharge. *Flow of surface water in a stream or canal, or the outflow of groundwater from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.*

Discharge Monitoring Report (DMR). *Report of effluent characteristics submitted by a municipal or industrial facility that has been granted an NPDES discharge permit.*

Discharge permits (under NPDES). *A permit issued by the EPA or a state regulatory agency that sets specific limits on the type and amount of pollutants that a municipality or industry can discharge to a receiving water; it also includes a compliance schedule for achieving those limits. The permit process was established under the National Pollutant Discharge Elimination System, under provisions of the Federal Clean Water Act.*

Dispersion. *The spreading of chemical or biological constituents, including pollutants, in various directions at varying velocities depending on the differential in-stream flow characteristics.*

Dissolved Oxygen (DO). The amount of oxygen in water. DO is a measure of the amount of oxygen available for biochemical activity in a waterbody.

Diurnal. *Actions or processes that have a period or a cycle of approximately one tidal-day or are completed within a 24-hour period and that recur every 24 hours. Also, the occurrence of an activity/process during the day rather than the night.*

DNA. Deoxyribonucleic acid. The genetic material of cells and some viruses.

Domestic wastewater. *Also called sanitary wastewater, consists of wastewater discharged from residences and from commercial, institutional, and similar facilities.*

Drainage basin. *A part of a land area enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into a receiving water. Also referred to as a watershed, river basin, or hydrologic unit.*

Dynamic model. *A mathematical formulation describing and simulating the physical behavior of a system or a process and its temporal variability.*

Dynamic simulation. *Modeling of the behavior of physical, chemical, and/or biological phenomena and their variations over time.*

Ecoregion. A region defined in part by its shared characteristics. These include meteorological factors, elevation, plant and animal speciation, landscape position, and soils.

Ecosystem. *An interactive system that includes the organisms of a natural community association together with their abiotic physical, chemical, and geochemical environment.*

Effluent. *Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc.*

Effluent guidelines. *The national effluent guidelines and standards specify the achievable effluent pollutant reduction that is attainable based upon the performance of treatment technologies employed within an industrial category. The National Effluent Guidelines Program was established with a phased approach whereby industry would first be required to meet interim limitations based on best practicable control technology currently available for existing sources (BPT). The second level of effluent limitations to be attained by industry was referred to as best available technology economically achievable (BAT), which was established primarily for the control of toxic pollutants.*

Effluent limitation. *Restrictions established by a state or EPA on quantities, rates, and concentrations in pollutant discharges.*

Endpoint. *An endpoint (or indicator/target) is a characteristic of an ecosystem that may be affected by exposure to a stressor. Assessment endpoints and measurement endpoints are two distinct types of endpoints commonly used by resource managers. An assessment endpoint is the formal expression of a valued environmental characteristic and should have societal relevance (an indicator). A measurement endpoint is the expression of an observed or measured response to a stress or disturbance. It is a measurable environmental characteristic that is related to the valued environmental characteristic chosen as the assessment endpoint. The numeric criteria that are part of traditional water quality standards are good examples of measurement endpoints (targets).*

Enhancement. *In the context of restoration ecology, any improvement of a structural or functional attribute.*

Erosion. The detachment and transport of soil particles by water and wind. Sediment resulting from soil erosion represents the single largest source of nonpoint pollution in the United States.

Eutrophication. The process of enrichment of water bodies by nutrients. Waters receiving excessive nutrients may become eutrophic, are often undesirable for recreation, and may not support normal fish populations.

Evapotranspiration. The combined effects of evaporation and transpiration on the water balance. Evaporation is water loss into the atmosphere from soil and water surfaces. Transpiration is water loss into the atmosphere as part of the life cycle of plants.

Fate of pollutants*. Physical, chemical, and biological transformation in the nature and changes of the amount of a pollutant in an environmental system. Transformation processes are pollutant-specific. Because they have comparable kinetics, different formulations for each pollutant are not required.*

Feedlot. *A confined area for the controlled feeding of animals. Tends to concentrate large amounts of animal waste that cannot be absorbed by the soil and, hence, may be carried to nearby streams or lakes by rainfall runoff.*

Flux. *Movement and transport of mass of any water quality constituent over a given period of time. Units of mass flux are mass per unit time.*

General Standard. A narrative standard that ensures the general health of state waters. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life (9VAC25-260-20). (4)

GIS. Geographic Information System. A system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth. (Dueker and Kjerne, 1989)

Ground water. *The supply of fresh water found beneath the earth's surface, usually in aquifers, which supply wells and springs. Because ground water is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants and leaking underground storage tanks.*

HSPF. Hydrological Simulation Program – Fortran. A computer simulation tool used to mathematically model nonpoint source pollution sources and movement of pollutants in a watershed.

Hydrograph*. A graph showing variation of stage (depth) or discharge in a stream over a period of time.*

Hydrologic cycle*. The circuit of water movement from the atmosphere to the earth and its return to the atmosphere through various stages or processes, such as precipitation, interception, runoff, infiltration, storage, evaporation, and transpiration.*

Hydrology*. The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.*

Impairment. A detrimental effect on the biological integrity of a water body that prevents attainment of the designated use.

IMPLND. An impervious land segment in HSPF. It is used to model land covered by impervious materials, such as pavement.

Indicator. *A measurable quantity that can be used to evaluate the relationship between pollutant sources and their impact on water quality.*

Indicator organism. *An organism used to indicate the potential presence of other (usually pathogenic) organisms. Indicator organisms are usually associated with the other organisms, but are usually more easily sampled and measured.*

Indirect causation. The induction of effects through a series of cause-effect relationships, so that the impaired resource may not even be exposed to the initial cause.

Indirect effects. Changes in a resource that are due to a series of cause-effect relationships rather than to direct exposure to a contaminant or other stressor.

Infiltration capacity. *The capacity of a soil to allow water to infiltrate into or through it during a storm.*

In situ. *In place; in situ measurements consist of measurements of components or processes in a full-scale system or a field, rather than in a laboratory.*

Interflow. Runoff that travels just below the surface of the soil.

Leachate. *Water that collects contaminants as it trickles through wastes, pesticides, or fertilizers. Leaching can occur in farming areas, feedlots, and landfills and can result in hazardous substances entering surface water, ground water, or soil.*

Limits (upper and lower). The lower limit equals the lower quartile – 1.5x(upper quartile – lower quartile), and the upper limit equals the upper quartile + 1.5x(upper quartile – lower quartile). Values outside these limits are referred to as outliers.

Loading, Load, Loading rate. *The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.*

Load allocation (LA). *The portion of a receiving waters loading capacity attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished (40 CFR 130.2(g)).*

Loading capacity (LC). *The greatest amount of loading a water can receive without violating water quality standards.*

Margin of safety (MOS). *A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody (CWA Section 303(d)(1)(C)). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by the EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the* *conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).*

Mass balance. *An equation that accounts for the flux of mass going into a defined area and the flux of mass leaving the defined area. The flux in must equal the flux out.*

Mass loading. *The quantity of a pollutant transported to a waterbody.*

Mean. The sum of the values in a data set divided by the number of values in the data set.

Metric ton (Mg or t). A unit of mass equivalent to 1,000 kilograms. An annual load of a pollutant is typically reported in metric tons per year (t/yr).

Metrics. Indices or parameters used to measure some aspect or characteristic of a water body's biological integrity. The metric changes in some predictable way with changes in water quality or habitat condition.

MGD. Million gallons per day. A unit of water flow, whether discharge or withdraw.

Mitigation. *Actions taken to avoid, reduce, or compensate for the effects of environmental damage. Among the broad spectrum of possible actions are those that restore, enhance, create, or replace damaged ecosystems.*

Model. Mathematical representation of hydrologic and water quality processes. Effects of land use, slope, soil characteristics, and management practices are included.

Monitoring. *Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.*

Mood's Median Test. A nonparametric (distribution-free) test used to test the equality of medians from two or more populations.

Most Probable Stressor(s): The stressor(s) with the most consistent information linking it with the poorer benthic and habitat metrics was considered to be the most probable stressor(s).

Narrative criteria*. Nonquantitative guidelines that describe the desired water quality goals.*

National Pollutant Discharge Elimination System (NPDES). *The national program for issuing, modifying, revoking and re-issuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Clean Water Act.*

Natural waters. *Flowing water within a physical system that has developed without human intervention, in which natural processes continue to take place.*

Nitrogen. An essential nutrient to the growth of organisms. Excessive amounts of nitrogen in water can contribute to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Nonpoint source. *Pollution that originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.*

Non-Stressor(s): Those stressors with data indicating normal conditions, without water quality standard violations, or without the observable impacts usually associated with a specific stressor, were eliminated as possible stressors.

Numeric targets*. A measurable value determined for the pollutant of concern, which, if achieved, is expected to result in the attainment of water quality standards in the listed waterbody.*

Numerical model. Model that approximates a solution of governing partial differential equations, which describe a natural process. The approximation uses a numerical discretization of the space and time components of the system or process.

Nutrient. An element or compound essential to life, including carbon, oxygen, nitrogen, phosphorus, and many others: as a pollutant, any element or compound, such as phosphorus or nitrogen, that in excessive amounts contributes to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Organic matter. *The organic fraction that includes plant and animal residue at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil or water sample.*

Parameter. A numerical descriptive measure of a population. Since it is based on the observations of the population, its value is almost always unknown.

Peak runoff*. The highest value of the stage or discharge attained by a flood or storm event; also referred to as flood peak or peak discharge.*

PERLND. A pervious land segment in HSPF. It is used to model a particular land use segment within a subwatershed (e.g. pasture, urban land, or crop land).

Permit. *An authorization, license, or equivalent control document issued by the EPA or an approved federal, state, or local agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.*

Permit Compliance System (PCS). *Computerized management information system that contains data on NPDES permit-holding facilities. PCS keeps extensive records on more* *than 65,000 active water-discharge permits on sites located throughout the nation. PCS tracks permit, compliance, and enforcement status of NPDES facilities.*

Phased/staged approach. *Under the phased approach to TMDL development, load allocations and wasteload allocations are calculated using the best available data and information recognizing the need for additional monitoring data to accurately characterize sources and loadings. The phased approach is typically employed when nonpoint sources dominate. It provides for the implementation of load reduction strategies while collecting additional data.*

Phosphorus. An essential nutrient to the growth of organisms. Excessive amounts of phosphorus in water can contribute to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Point source. *Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.*

Pollutant. *Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water. (CWA section 502(6)).*

Pollution. *Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.*

Polycyclic aromatic hydrocarbons (**PAH**s) are chemical compounds that consist of fused aromatic rings and do not contain heteroatoms or carry substituents. PAHs occur in oil, coal, and tar deposits, and are produced as byproducts of fuel burning (whether fossil fuel or biomass). As a pollutant, they are of concern because some compounds have been identified as carcinogenic, mutagenic, and teratogenic.

Possible Stressor(s): Those stressors with data indicating possible links, but inconclusive data, were considered to be possible stressors.

Postaudit. *A subsequent examination and verification of a model's predictive performance following implementation of an environmental control program.*

Privately owned treatment works*. Any device or system that is (a) used to treat wastes from any facility whose operator is not the operator of the treatment works and (b) not a publicly owned treatment works.*

Public comment period*. The time allowed for the public to express its views and concerns regarding action by the EPA or states (e.g., a* Federal Register *notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).*

Publicly owned treatment works (POTW). *Any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.*

Quartile. The 25th, 50th, and 75th percentiles of a data set. A percentile (p) of a data set ordered by magnitude is the value that has at most p% of the measurements in the data set below it, and (100-p)% above it. The 50th quartile is also known as the median. The 25th and 75th quartiles are referred to as the lower and upper quartiles, respectively.

Rapid Bioassessment Protocol II (RBP II). A suite of measurements based on a quantitative assessment of benthic macroinvertebrates and a qualitative assessment of their habitat. RBP II scores are compared to a reference condition or conditions to determine to what degree a water body may be biologically impaired.

Reach. Segment of a stream or river.

Receiving waters. *Creeks, streams, rivers, lakes, estuaries, ground-water formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.*

Reference Conditions. The chemical, physical, or biological quality or condition exhibited at either a single site or an aggregation of sites that are representative of non-impaired conditions for a watershed of a certain size, land use distribution, and other related characteristics. Reference conditions are used to describe reference sites.

Reserve capacity*. Pollutant loading rate set aside in determining stream waste load allocation, accounting for uncertainty and future growth.*

Residence time. *Length of time that a pollutant remains within a section of a stream or river. The residence time is determined by the streamflow and the volume of the river reach or the average stream velocity and the length of the river reach.*

Restoration*. Return of an ecosystem to a close approximation of its presumed condition prior to disturbance.*

Riparian areas. *Areas bordering streams, lakes, rivers, and other watercourses. These areas have high water tables and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.*

Riparian zone*. The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.*

Roughness coefficient*. A factor in velocity and discharge formulas representing the effects of channel roughness on energy losses in flowing water. Manning's "n" is a commonly used roughness coefficient.*

Runoff. *That part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.*

Seasonal Kendall test. A statistical tool used to test for trends in data, which is unaffected by seasonal cycles. (Gilbert, 1987)

Sediment. In the context of water quality, soil particles, sand, and minerals dislodged from the land and deposited into aquatic systems as a result of erosion.

Septic system*. An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives waste from a residence or business and a drain field or subsurface absorption system consisting of a series of percolation lines for the disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.*

Sewer. *A channel or conduit that carries wastewater and storm water runoff from the source to a treatment plant or receiving stream. Sanitary sewers carry household, industrial, and commercial waste. Storm sewers carry runoff from rain or snow. Combined sewers handle both.*

Simulation*. The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.*

Slope. *The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04), degrees (2 degrees 18 minutes), or percent (4 percent).*

Source. An origination point, area, or entity that releases or emits a stressor. A source can alter the normal intensity, frequency, or duration of a natural attribute, whereby the attribute then becomes a stressor.

Spatial segmentation*. A numerical discretization of the spatial component of a system into one or more dimensions; forms the basis for application of numerical simulation models.*

Staged Implementation. A process that allows for the evaluation of the adequacy of the TMDL in achieving the water quality standard. As stream monitoring continues to occur, staged or phased implementation allows for water quality improvements to be recorded as they are being achieved. It also provides a measure of quality control, and it helps to ensure that the most cost-effective practices are implemented first.

Stakeholder. Any person with a vested interest in the TMDL development.

Standard. In reference to water quality (e.g. 200 cfu/100 mL geometric mean limit).

Standard deviation. A measure of the variability of a data set. The positive square root of the variance of a set of measurements.

Standard error. The standard deviation of a distribution of a sample statistic, esp. when the mean is used as the statistic.

Statistical significance. An indication that the differences being observed are not due to random error. The p-value indicates the probability that the differences are due to random error (i.e. a low p-value indicates statistical significance).

Steady-state model. *Mathematical model of fate and transport that uses constant values of input variables to predict constant values of receiving water quality concentrations. Model variables are treated as not changing with respect to time.*

Storm runoff. *Storm water runoff, snowmelt runoff, and surface runoff and drainage; rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate lower than rainfall intensity, but instead flows onto adjacent land or into waterbodies or is routed into a drain or sewer system.*

Streamflow. *Discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff" since streamflow may be applied to discharge whether or not it is affected by diversion or regulation.*

Stream Reach. A straight portion of a stream.

Stream restoration. *Various techniques used to replicate the hydrological, morphological, and ecological features that have been lost in a stream because of urbanization, farming, or other disturbance.*

Stressor. Any physical, chemical, or biological entity that can induce an adverse response. [2]

Surface area. *The area of the surface of a waterbody; best measured by planimetry or the use of a geographic information system.*

Surface runoff. *Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants.*

Surface water. *All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.*

Suspended Solids. Usually fine sediments and organic matter. Suspended solids limit sunlight penetration into the water, inhibit oxygen uptake by fish, and alter aquatic habitat.

Technology-based standards*. Effluent limitations applicable to direct and indirect sources that are developed on a category-by-category basis using statutory factors, not including water quality effects.*

Timestep. An increment of time in modeling terms. The smallest unit of time used in a mathematical simulation model (e.g. 15-minutes, 1-hour, 1-day).

Ton (T). A unit of measure of mass equivalent to 2,200 English lbs.

Topography. *The physical features of a geographic surface area including relative elevations and the positions of natural and man-made features.*

Total Dissolved Solids (TDS). A measure of the concentration of dissolved inorganic chemicals in water.

Total Maximum Daily Load (TMDL). *The sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.*

TMDL Implementation Plan. A document required by Virginia statute detailing the suite of pollution control measures needed to remediate an impaired stream segment. The plans are also required to include a schedule of actions, costs, and monitoring. Once implemented, the plan should result in the previously impaired water meeting water quality standards and achieving a "fully supporting" use support status.

Transport of pollutants (in water). *Transport of pollutants in water involves two main processes: (1) advection, resulting from the flow of water, and (2) dispersion, or transport due to turbulence in the water.*

Tributary. *A lower order-stream compared to a receiving waterbody. "Tributary to" indicates the largest stream into which the reported stream or tributary flows.*

Urban Runoff. Surface runoff originating from an urban drainage area including streets, parking lots, and rooftops.

Validation (of a model). *Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical processes under investigation. A validated model will have also been tested to ascertain whether it accurately and correctly solves the equations being used to define the system simulation.*

Variance. A measure of the variability of a data set. The sum of the squared deviations (observation – mean) divided by (number of observations) – 1.

VADACS. Virginia Department of Agriculture and Consumer Services.

VADCR. Virginia Department of Conservation and Recreation.

VADEQ. Virginia Department of Environmental Quality.

VDH. Virginia Department of Health.

Wasteload allocation (WLA). *The portion of a receiving waters' loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).*

Wastewater. *Usually refers to effluent from a sewage treatment plant. See also Domestic wastewater.*

Wastewater treatment*. Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.*

Water quality*. The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.*

Water quality-based permit*. A permit with an effluent limit more stringent than one based on technology performance. Such limits might be necessary to protect the designated use of receiving waters (e.g., recreation, irrigation, industry, or water supply).*

Water quality criteria*. Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by the EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.*

Water quality standard. *Law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.*

Watershed. *A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.*

WQIA. Water Quality Improvement Act.

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APPENDIX A

Frequency plots for fecal coliform and E.coli at VADEQ monitoring stations

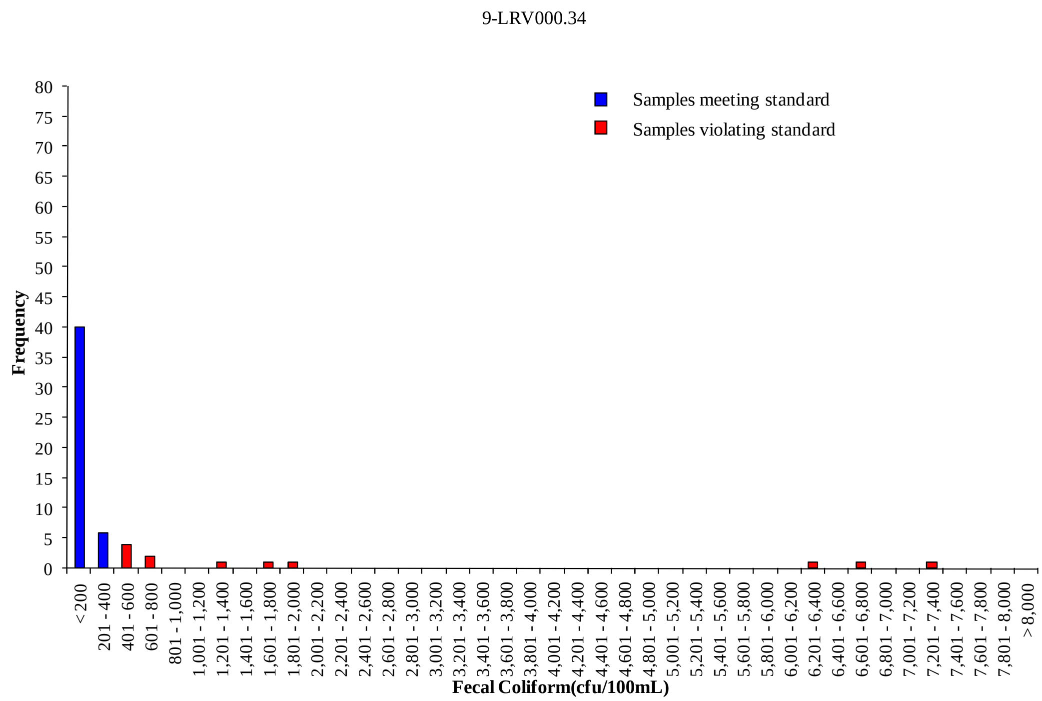

Figure A. 1 Frequency analysis of fecal coliform concentrations at station 9-LRV000.34 in the Little River watershed.

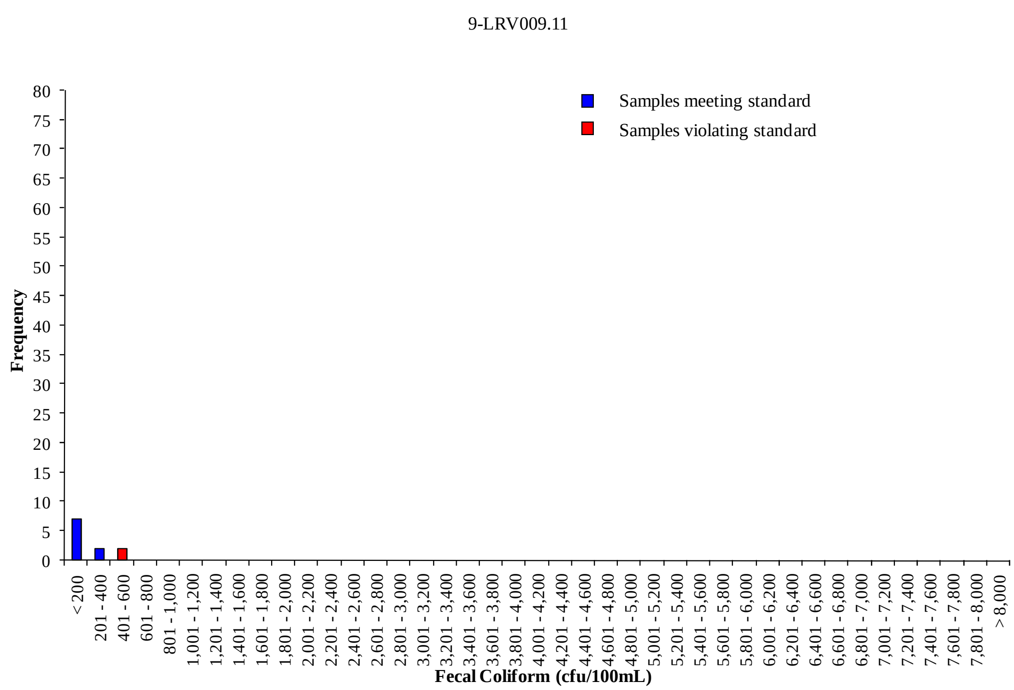

Figure A. 2 Frequency analysis of fecal coliform concentrations at station 9-LRV009.11 in the Little River watershed.

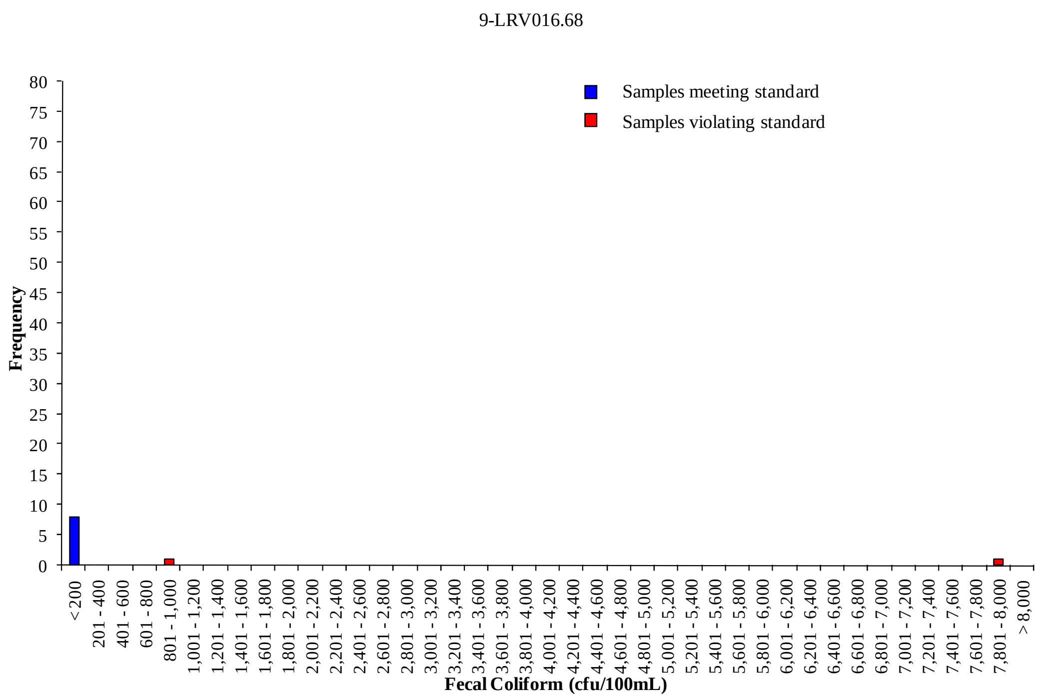

Figure A. 3 Frequency analysis of fecal coliform concentrations at station 9-LRV016.68 in the Little River watershed.

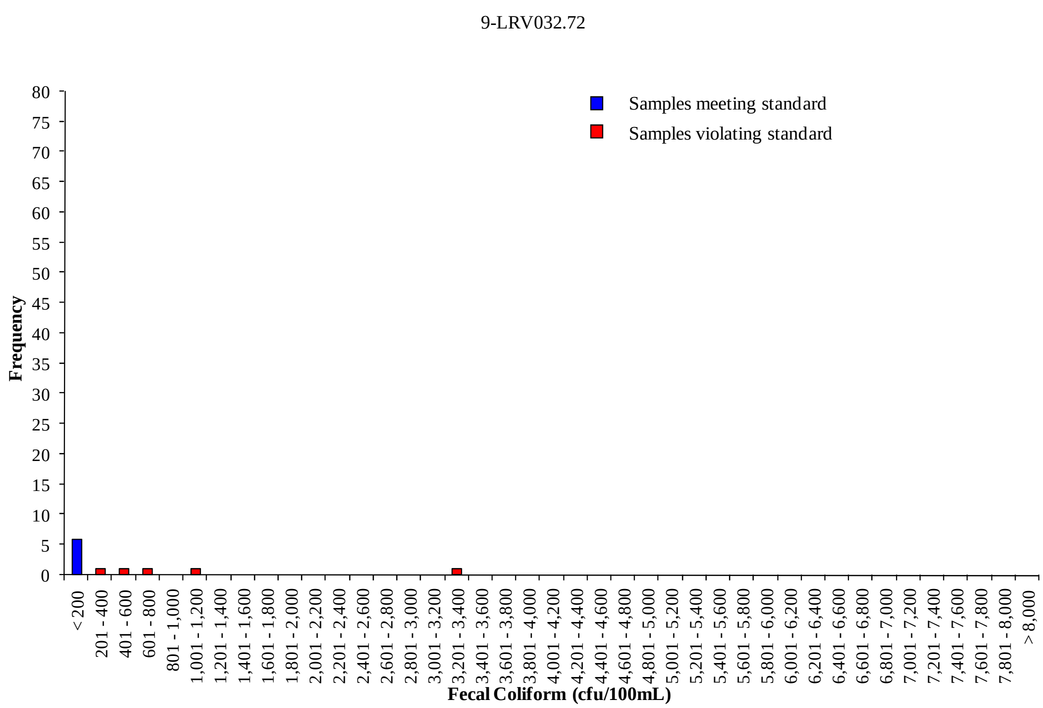

Figure A. 4 Frequency analysis of fecal coliform concentrations at station 9-LRV032.72 in the Little River watershed.

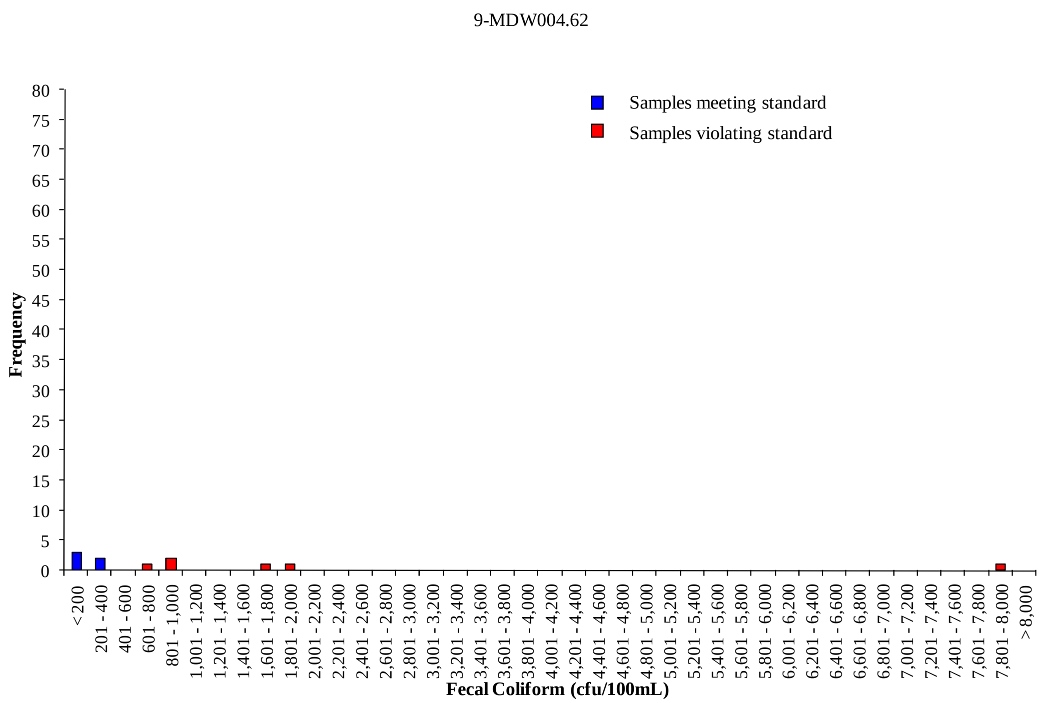

Figure A. 5 Frequency analysis of fecal coliform concentrations at station 9-MDW004.62 in the Little River watershed.

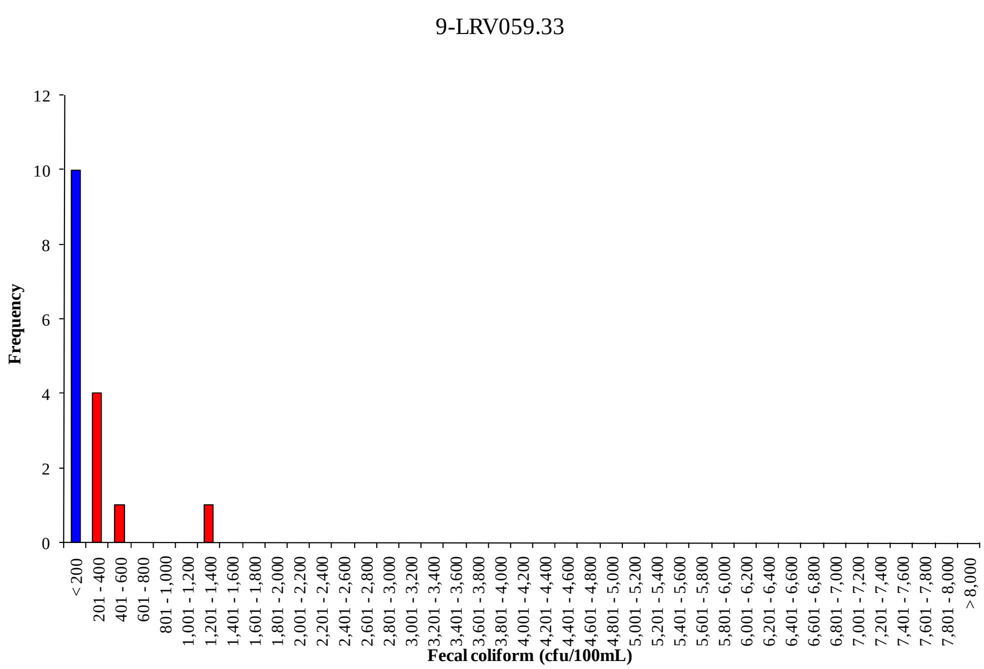

Figure A. 6 Frequency analysis of fecal coliform concentrations at station 9-LRV059.33 in the Little River watershed.

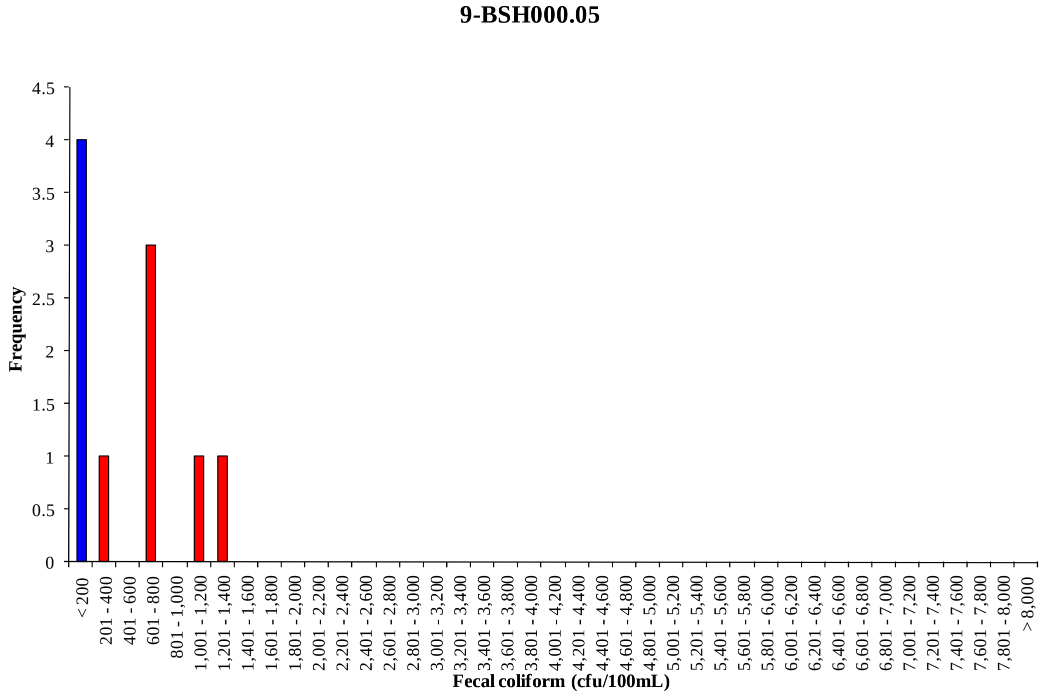

Figure A. 7 Frequency analysis of fecal coliform concentrations at station 9-BSH000.05 in the Little River watershed.

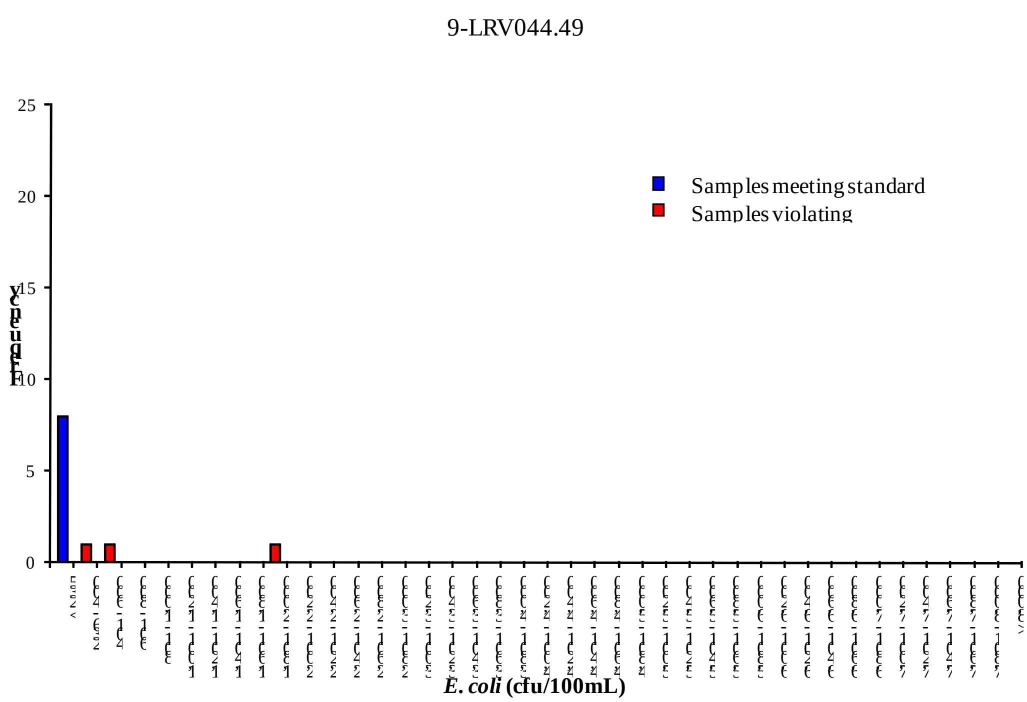

Figure A. 8 Frequency analysis of *E.coli* concentrations at station 9-LRV044.49 in the Little River watershed.

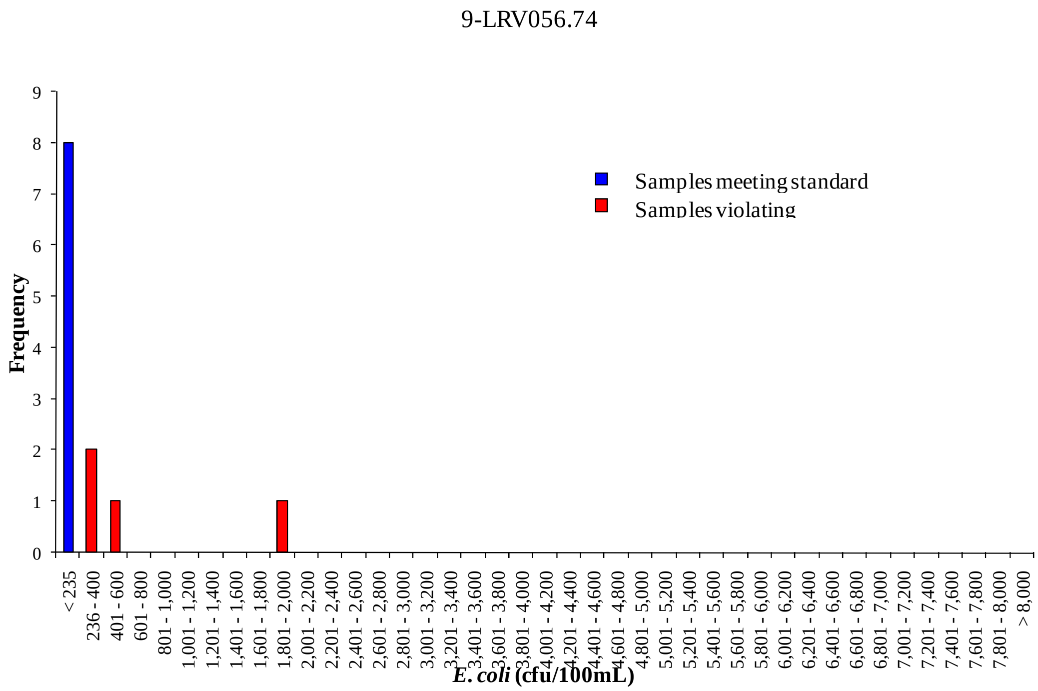

Figure A. 9 Frequency analysis of *E.coli* concentrations at station 9-LRV056.74 in the Little River watershed.

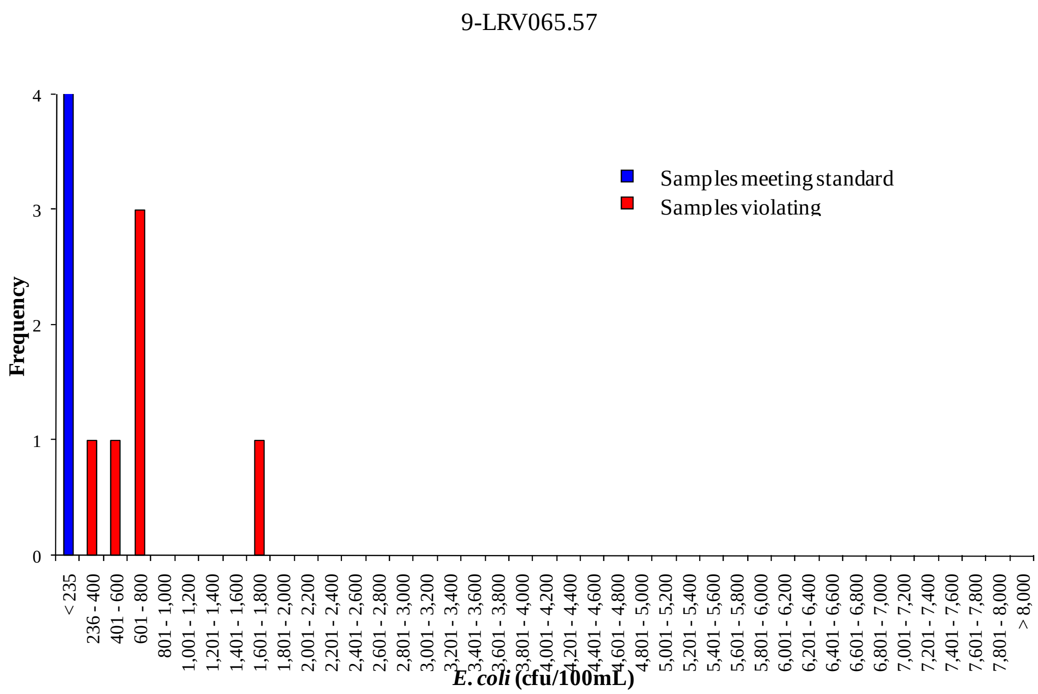

Figure A. 10 Frequency analysis of *E.coli* concentrations at station 9-LRV065.57 in the Little River watershed.

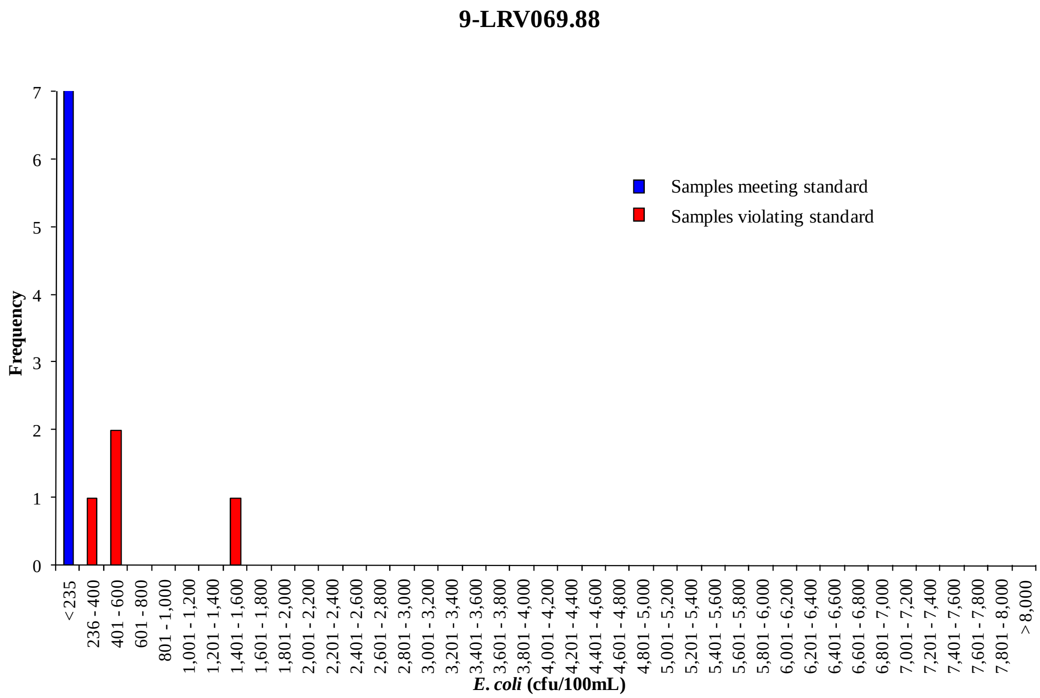

Figure A. 11 Frequency analysis of *E.coli* concentrations at station 9-LRV069.88 in the Little River watershed.

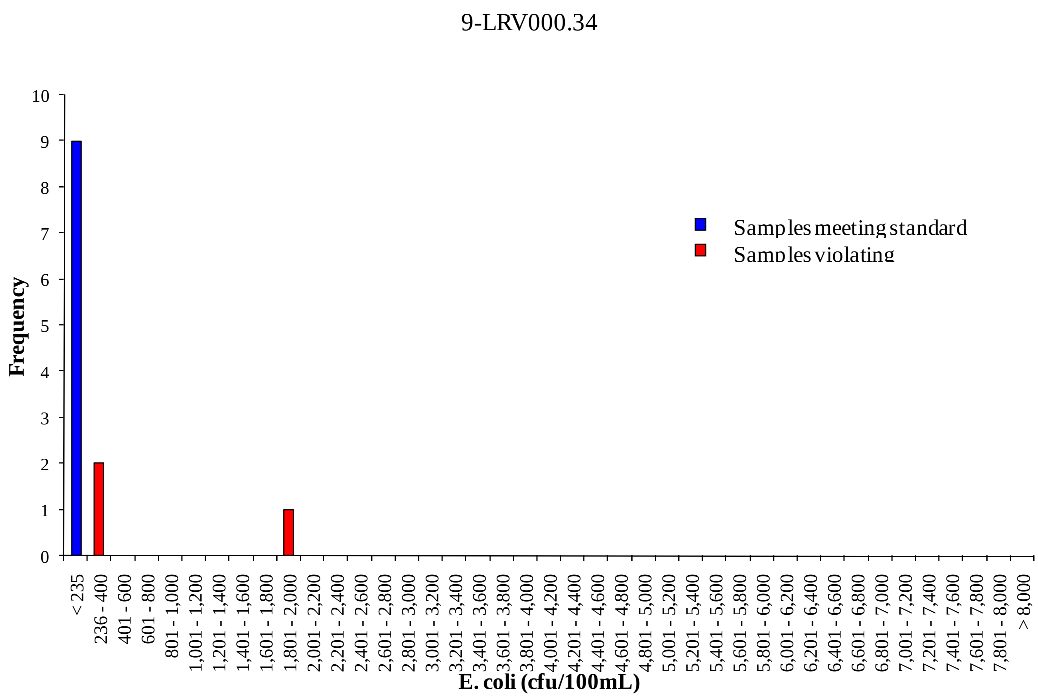

Figure A. 12 Frequency analysis of *E.coli* concentrations at station 9-LRV000.34 in the Little River watershed.

9-LRV009.11

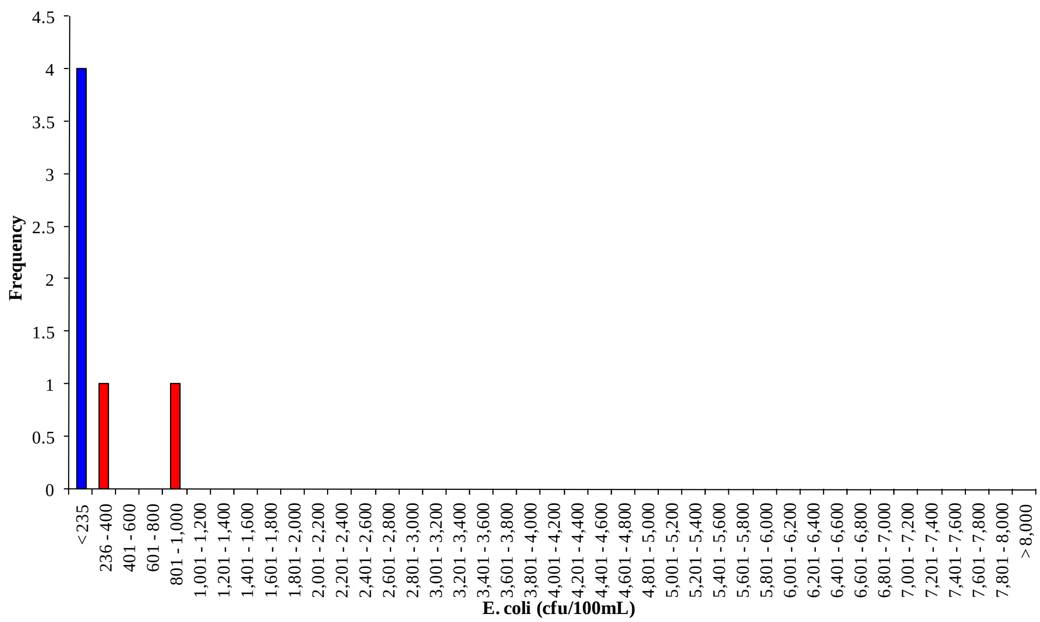

Figure A. 13 Frequency analysis of *E.coli* concentrations at station 9-LRV009.11 in the Little River watershed.

9-LRV016.68

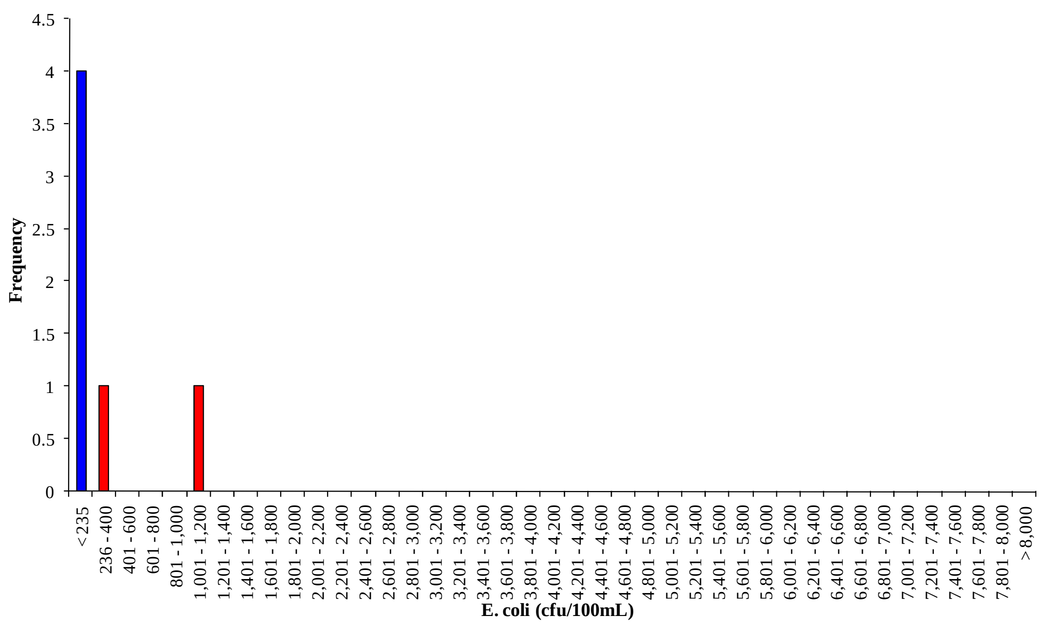

Figure A. 14 Frequency analysis of *E.coli* concentrations at station 9-LRV016.68 in the Little River watershed.

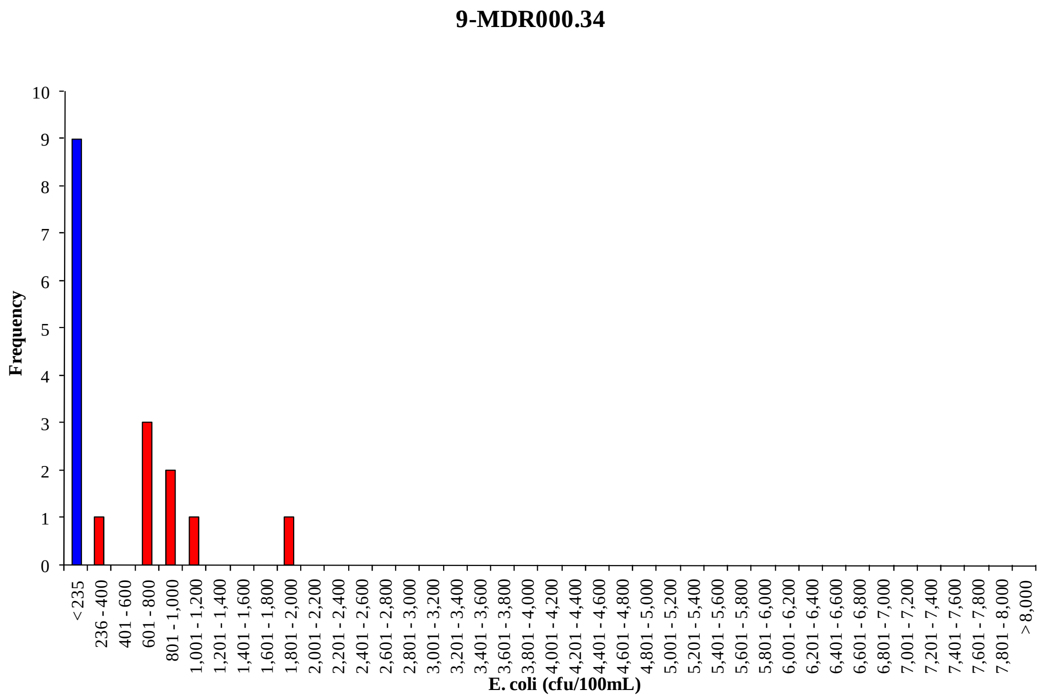

Figure A. 15 Frequency analysis of *E.coli* concentrations at station 9-MDR000.34 in the Little River watershed.

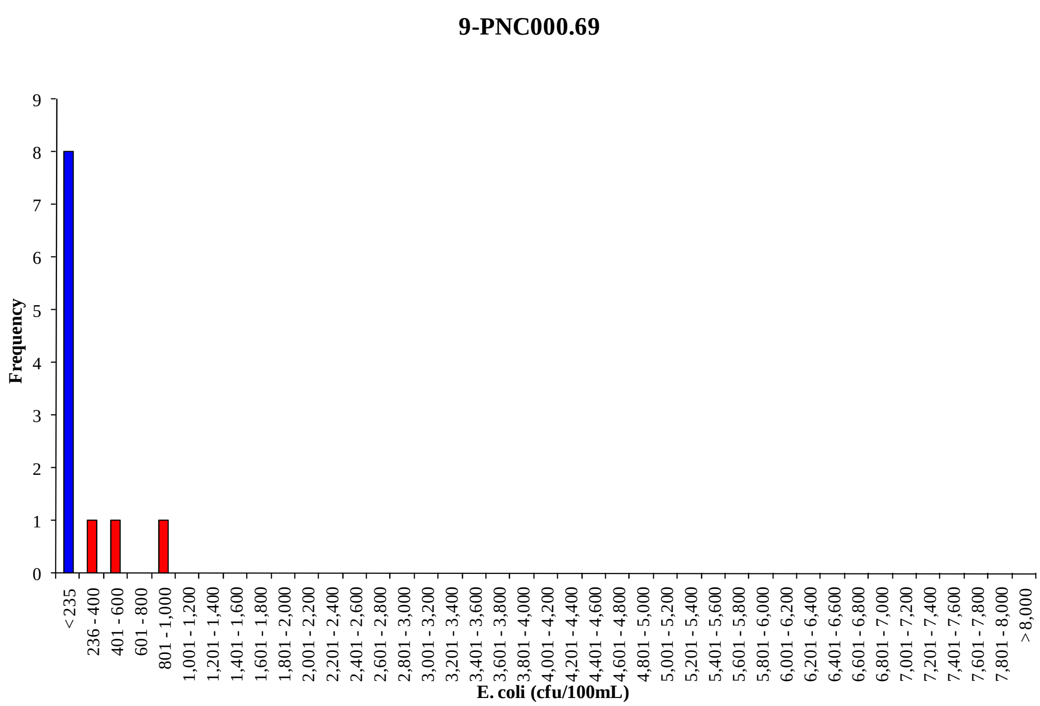

Figure A. 16 Frequency analysis of *E.coli* concentrations at station 9-PNC000.69 in the Little River watershed.

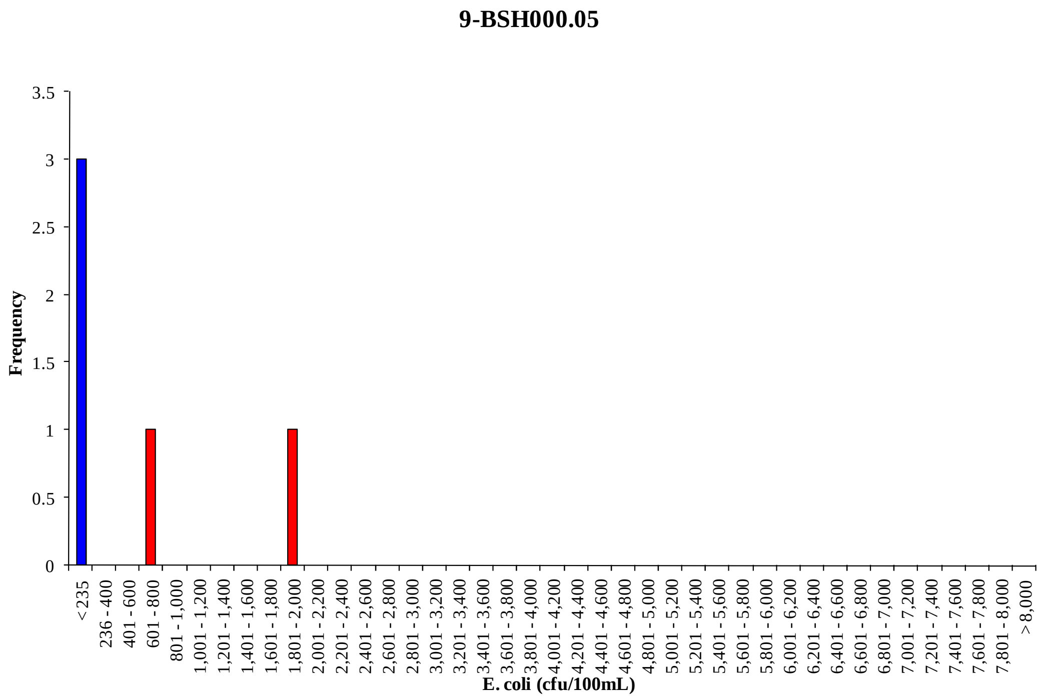

Figure A. 17 Frequency analysis of *E.coli* concentrations at station 9-BSH000.05 in the Little River watershed.

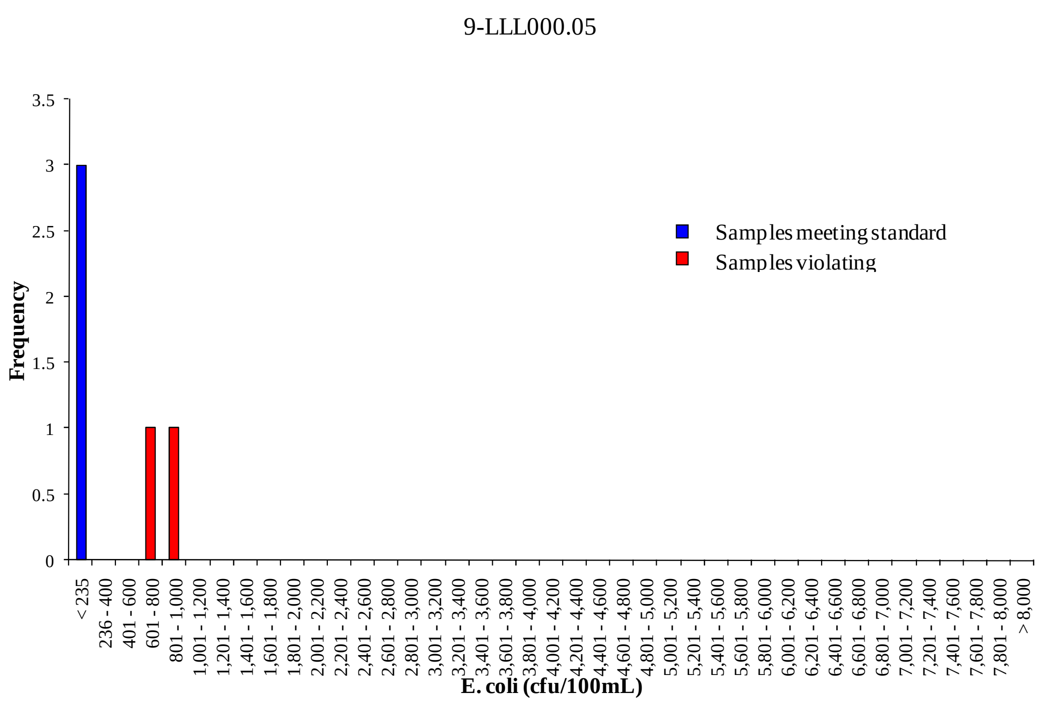

Figure A. 18 Frequency analysis of *E.coli* concentrations at station 9-LLL000.05 in the Little River watershed.

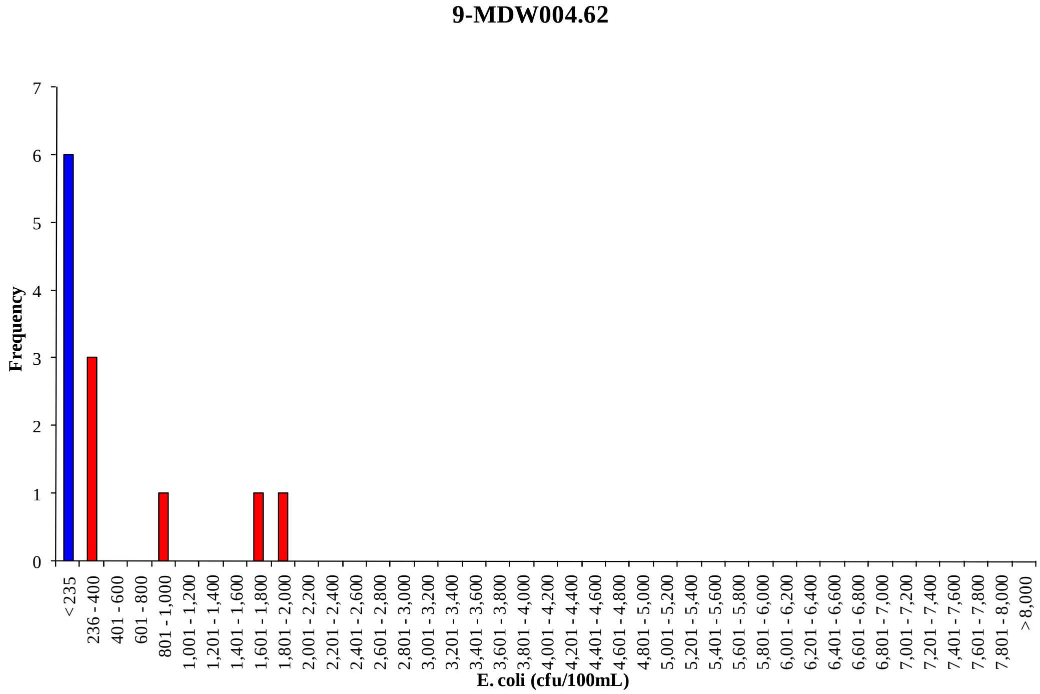

Figure A. 19 Frequency analysis of *E.coli* concentrations at station 9-MDW004.62 in the Little River watershed.

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APPENDIX B

Bacteria modeling procedure: Linking the sources to the endpoint

Bacteria modeling procedure: Linking the sources to the endpoint

Establishing the relationship between in-stream water quality and the source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired water quality endpoint. In the development of TMDLs in the Littler River study area, the relationship was defined through computer modeling based on data collected throughout the watersheds. Monitored flow and water quality data were then used to verify that the relationships developed through modeling were accurate. There are five basic steps in the development and use of a water quality model: model selection, source assessment, selection of a representative modeling period, model calibration, model validation, and model simulation.

Model selection involves identifying an approved model that is capable of simulating the pollutants of interest with the available data. Source assessment involves identifying and quantifying the potential sources of pollutants in the watershed. Selection of a representative period involves the identification of a time period that accounts for critical conditions associated with all potential sources within the watershed. Calibration is the process of comparing modeled data to observed data and making appropriate adjustments to model parameters to minimize the error between observed and simulated events. Validation is the process of comparing modeled data to observed data during a period other than that used for calibration, with the intent of assessing the capability of the model in hydrologic conditions other than those used during calibration. During validation, no adjustments are made to model parameters. Once a suitable model is constructed, the model is then used to predict the effects of current loadings and potential management practices on water quality.

Modeling Framework Selection

The USGS Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to simulate streamflow, overland runoff and to perform bacteria TMDL allocations.

The HSPF model simulates a watershed by dividing it up into a network of stream segments (referred to in the model as RCHRES), impervious land areas (IMPLND) and pervious land areas (PERLND). Each subwatershed contains a single RCHRES, modeled as an open channel, and numerous PERLNDs and IMPLNDs, representing the various land uses in that subwatershed. Water and pollutants from the land segments in a given subwatershed flow into the RCHRES in that subwatershed. Point discharges and withdrawals of water and pollutants are simulated as flowing directly to or withdrawing from a particular RCHRES as well. Water and pollutants from a given RCHRES flow into the next downstream RCHRES. The network of RCHRESs is constructed to mirror the configuration of the stream segments found in the physical world. Therefore, activities simulated in one impaired stream segment affect the water quality downstream in the model.

The HSPF model is a continuous simulation model that can account for nonpoint source (NPS) pollutants in runoff, as well as pollutants entering the flow channel from point sources. In establishing the existing and allocation conditions, seasonal variations in hydrology, climatic conditions, and watershed activities were explicitly accounted for in the model. The use of HSPF allowed consideration of seasonal aspects of precipitation patterns within the watershed.

Model Setup

Daily precipitation data was available within the watershed at the Floyd 2 NE NCDC Coop station # 443071. Missing values were filled using daily precipitation from the Willis NCDC Coop station # 449169 and Christiansburg NCDC Coop station 441692. The final filled daily precipitation was disaggregated using the hourly station data.

Subwatersheds

To adequately represent the spatial variation in the watershed, the Little River Watershed drainage area was divided into twenty three (23) subwatersheds (Figure B.1). The rationale for choosing these subwatersheds was based on the availability of water quality and flow data, the stream network configuration, and the limitations of the HSPF model. Model output from previously conducted bacteria TMDLs were inputted into the model at the appropriate spatial location as a time series of flow and bacteria concentration. Output from the Mill Creek TMDL was used as an input to subwatershed 27 and output from Dodd Creek TMDL was used as input to subwatershed 20. Nineteen of these subwatersheds were used in hydrologic calibration since they were upstream of the flow gage with observed data (outlet of subwatershed 3). The entire set of 23 subwatersheds was used in the bacteria calibration.

Figure B.1 shows all subwatersheds, which were used to achieve the unified model. Table B.1 notes the subwatersheds contained within each impairment, the impaired stream segments, and the outlet subwatershed for each impairment.

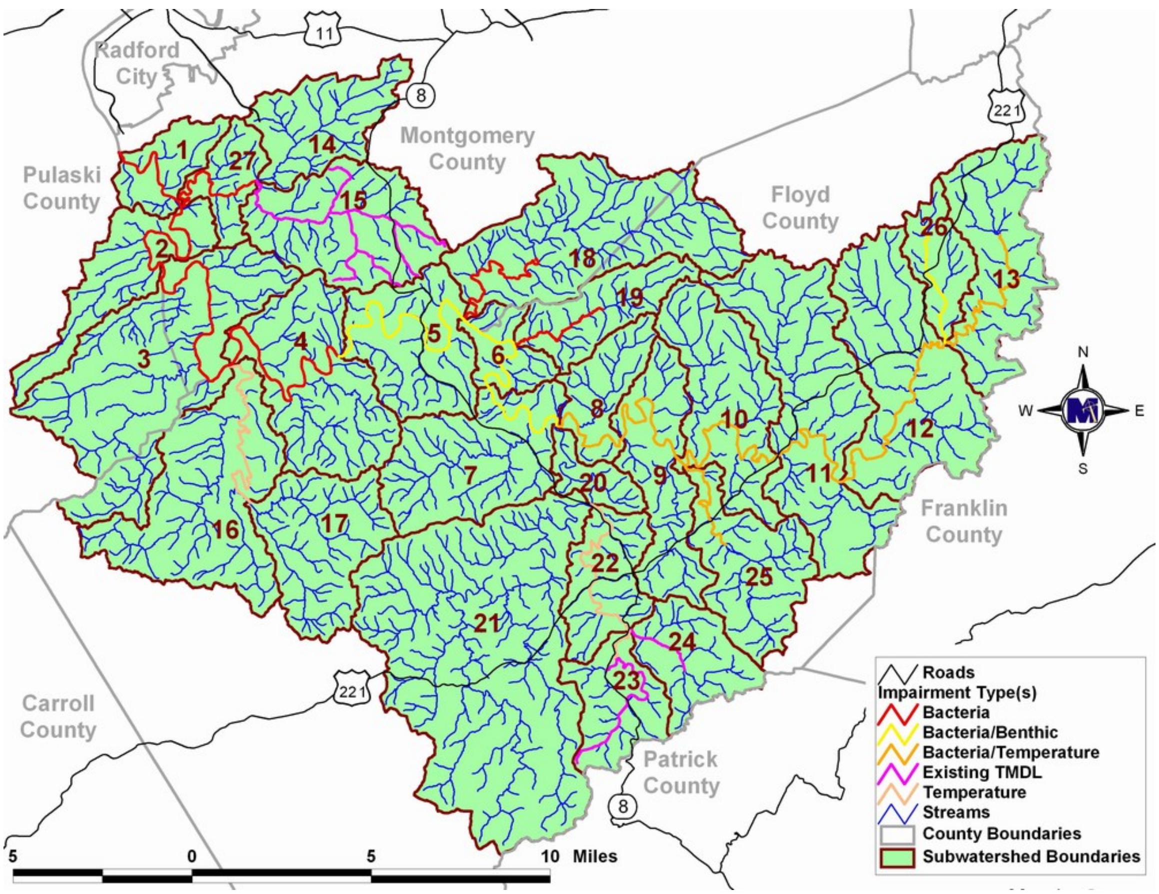

Figure B. 1 All subwatersheds delineated for modeling in the Little River study area.

Table B. 1 Impairments and subwatersheds within the Little River study area.

Impairment	Impaired Subwatershed(s)	Outlet	Contributing Subwatersheds
Meadow Creek VAW-N21R_MDW01A00	27	27	14,27,Mill Creek TMDL
Brush Creek VAW-N21R_BSH01A04	18	18	18
Laurel Creek VAW-N21R_LLL01A04	19	19	19
Little River VAW-N21R_LRV04A00	1	1	1,2,3,4,5,6,7,8,9,10,11,12,13,14,16, 17,18,19,20,21,25,26,27,Mill Creek TMDL, Dodd Creek TMDL
Little River VAW-N21R_LRV05A00	2,3	2	2,3,4,5,6,7,8,9,10,11,12,13,16,17,18 ,19,20,21,25, 26
Little River VAW-N21R_LRV06A00	4	4	4,5,6,7,8,9,10,11,12,13,18,19,20,21, 25, 26, Dodd Creek TMDL
Little River (Reservoir) VAW-N21L_LRV01A02	1	1	1,2,3,4,5,6,7,8,9,10,11,12,13,14,16, 17,18,19,20,21,25,26,27,Mill Creek TMDL, Dodd Creek TMDL
Meadow Run VAW-N19R_MDR01A04	26	26	26
Pine Creek VAW-N19R_PNC01A06	25	25	25
Little River VAW-N19R_LRV01A00	8,9	8	8,9,10,11,12,13,25,26
Little River VAW-N19R_LRV02A00	10,11	10	10,11,12,13,26
Little River VAW-N19R_LRV03A00	12,13	12	12,13,26
Little River VAW-N21R_LRV06A04	5,6	5	5,6,7,8,9,10,11,12,13,19,20,21,25, 26,Dodd Creek TMDL
Little River VAW-N21R_LRV07A00	7	7	7,8,9,10,11,12,13,20,21,25,26
Little River VAW-N21R_LRV01A00	1	1	1,2,3,4,5,6,7,8,9,10,11,12,13,14,16, 17,18,19,20,21,25,26,27,Mill Creek TMDL, Dodd Creek TMDL
Little River VAW-N21R_LRV03A00	1	1	1,2,3,4,5,6,7,8,9,10,11,12,13,14,16, 17,18,19,20,21,25,26,27,Mill Creek TMDL, Dodd Creek TMDL

In an effort to standardize modeling procedures across the state, VADEQ has required that fecal bacteria models be run at a 1-hour time-step. The HSPF model requires that the time of concentration in any subwatershed be greater than the time-step being used for the model. These modeling constraints as well as the desire to maintain a spatial distribution of watershed characteristics and associated parameters were considered in the delineation of subwatersheds. The spatial division of the watersheds allowed for a more refined representation of pollutant sources, and a more realistic description of hydrologic factors in the watersheds.

Land Uses

Nine land uses were identified in the watershed. These land uses were obtained by merging different sources including the MRLC land use grid, and aerial photography of the region. The nine land use types are given in Table B.2. Within each subwatershed, up to the nine land use types were represented. Each land use in each subwatershed has hydrologic parameters (*e.g.*, average slope length) and pollutant behavior parameters (*e.g.*, *E. coli* accumulation rate) associated with it. These land use types are represented in HSPF as pervious land segments (PERLNDs) and impervious land segments (IMPLNDs). Impervious areas in the watershed are represented in three IMPLND types, while there are nine PERLND types, each with parameters describing a particular land use. Some IMPLND and PERLND parameters (*e.g.*, slope length) vary with the particular subwatershed in which they are located. Others vary with the season (*e.g.*, upper zone storage) to account for plant growth, die-off, and removal.

Figure B.2 shows the percentage pervious for each land use as used in modeling the Little River study area. Table B.3 shows the breakdown of land uses within the drainage area. These acreages represent only what is within the boundaries of the Little River study area and do not include acreage within the two previously developed TMDLs (Mill Creek and Dodd Creek).

Table B. 2 Consolidated land use categories for the Little River drainage area used in HSPF modeling.

TMDL Land use Categories	Pervious / Impervious (%)
Barren	Pervious (90%) Impervious (10%)
Cropland	Pervious (100%)
Commercial	Pervious (60%) Impervious (40%)
Developed	Pervious (80%) Impervious (20%)
Forest	Pervious (100%)
Livestock Access	Pervious (100%)
Pasture	Pervious (100%)
water	Pervious (100%)
Wetland	Pervious (100%)

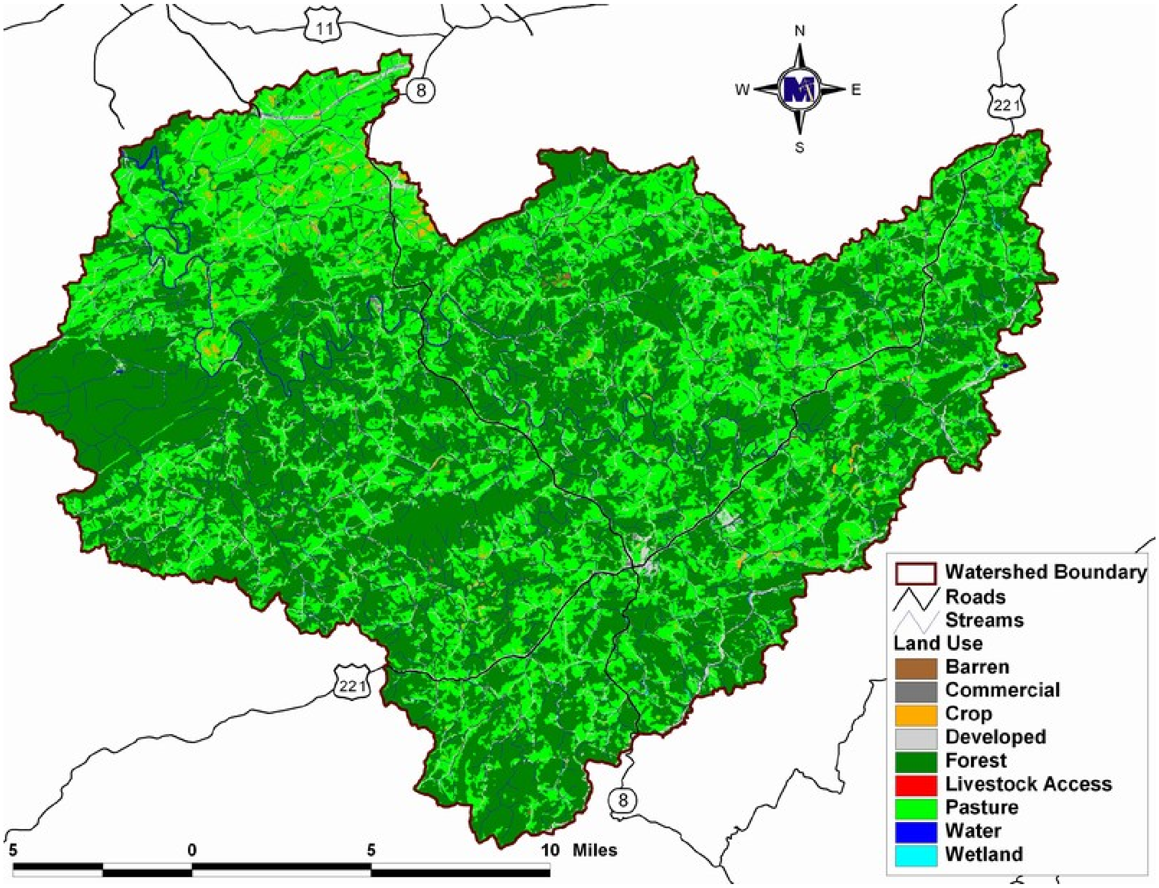

Figure B. 2 Land uses in the Little River study area watershed.

Table B. 3 Area of land use types in acres in the Little River study area.

Impairment	Barren	Commercial	Cropland	Developed	Forest	Livestock Access	Pasture/ Hay	Water	Wetland	Total Acres
Little River Watershed	193 (0.1%)	192 (0.1%)	1,185 (0.59%)	9,613 (4.78%)	113,715 (56.55%)	1,136 (0.56%)	73,265 (36.44%)	1,534 (0.76%)	235 (0.12%)	201,068

Die-off of fecal bacteria can be handled implicitly or explicitly. For land-applied fecal matter (mechanically applied and deposited directly), die-off was addressed implicitly through monitoring and modeling. Samples of collected waste prior to land application (*i.e.*, dairy waste from loafing areas) were collected and analyzed by MapTech. Therefore, die-off is implicitly accounted for through the sample analysis. Die-off occurring in the field was represented implicitly through model parameters such as the maximum accumulation and the 90% wash off rate, which were adjusted during the calibration of the model. These parameters were assumed to represent not only the delivery mechanisms, but the bacteria die-off as well. Once the fecal bacteria entered the stream, the general decay module of HSPF was incorporated, thereby explicitly addressing the die-off rate. The general decay module uses a first order decay function to simulate die-off.

Stream Characteristics

HSPF requires that each stream reach be represented by constant characteristics (*e.g.*, stream geometry and resistance to flow). This data are entered into HSPF via the Hydraulic Function Tables (F-tables). The F-tables developed consist of four columns: depth (ft), area (ac), volume (ac-ft), and discharge (ft^3/s). The depth represents the possible range of flow, with a maximum value beyond what would be expected for the reach. The area listed is the surface area of the flow in acres. The volume corresponds to the total volume in the reach, and is reported in acre-feet. The discharge is simply the stream outflow, in cubic feet per second.

In order to develop the entries for the F-tables, a combination of the NRCS Regional Hydraulic Geometry Curves (NRCS, 2008b) and Digital Elevation Models (DEM) data was used. The NRCS has developed empirical formulas for estimating stream top width, cross-sectional area, average depth, and flow rate, at bank-full depth as functions of the drainage area for regions of the United States. Appropriate equations were selected based on the geographic location of the Little River watershed. Using these NRCS equations, an entry was developed in the F-table that represented a bank-full situation for the streams at each subwatershed outlet. A profile perpendicular to the channel was generated showing the stream profile height with distance for each subwatershed outlet

(Figure B.3). Consecutive entries to the F-table are generated by estimating the volume of water and surface area in the reach at incremental depths taken from the profile. An example of an F-table used in HSPF is shown in Table B.4.

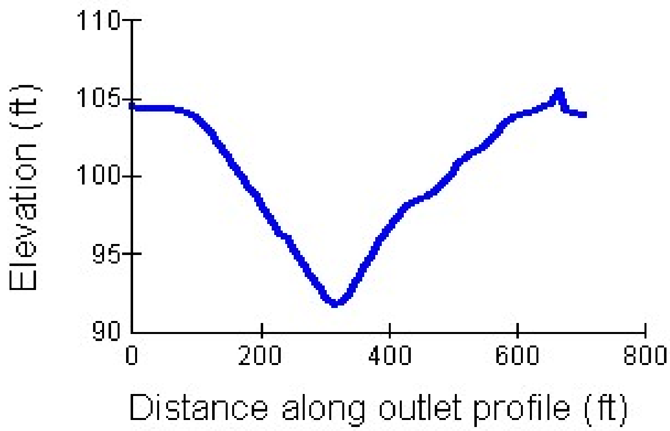

Figure B. 3 Stream profile representation in HSPF.

Table B. 4 Example of an F-table calculated for the HSPF model.

Depth (ft)	Area (ac)	Volume (ac-ft)	Outflow (ft^3/s)
0	0	0	0
3.28	0.71	1.41	17.07
6.56	1.89	5.15	45.23
9.84	2.54	12.18	85.02
13.12	4.77	24.80	152.82
16.40	56.55	77.51	637.72
19.68	1,047.22	1,635.10	18,846.85
22.96	2,875.31	7,405.99	69,827.77
26.24	3,495.32	18,464.40	133,806.76
29.52	4,426.89	31,720.10	160,393.97

Selection of Representative Modeling Periods

Selection of the modeling period was based on two factors: availability of data (discharge and water-quality) and the need to represent critical hydrological conditions. Mean daily discharge at USGS Gaging Station 03170000 in the Little River at Graysontown, Virginia was available from 1928 through 2010. The modeling period was selected to include the VADEQ assessment period from July 1992 through December 2008 that led to the inclusion of the impaired streams in this TMDL study area on the 1996, 1998, 2002, 2004, 2006 and 2008 Section 303(d) lists. Hydrologic calibration period was October 1993 to September 1996 and hydrologic validation period was October 2005 to September 2008. The fecal concentration data from this period were evaluated to determine the relationship between concentration and the level of flow in the stream. High concentrations of fecal coliform were recorded in all flow regimes, thus it was concluded that the critical hydrological condition included a wide range of wet and dry seasons. Bacteria model calibration and validation were conducted for the period of October 2000 to September 2003 and October 1997 to September 2000, respectively.

The hydrology calibration/validation/water quality calibration and validation time period, have both the high and low daily average streamflow and precipitation, which represent the high and low flow critical regimes (Figures B.4 and B.5). The figures are shown here to demonstrate the historical annual and seasonal stream flow and precipitation and how the selected time period encompasses a representative range of values. Table B.5 shows the statistical comparison between calibration/validation time periods and historic time period.

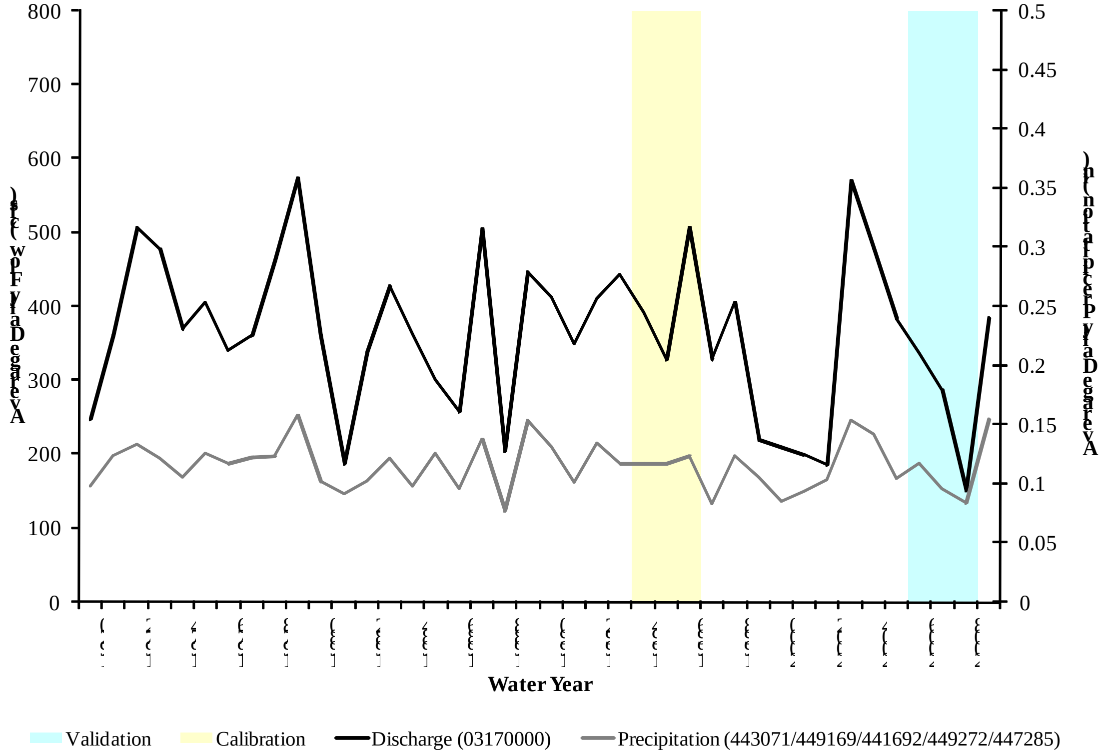

Figure B. 4 **Modeling time periods, annual historical flow (USGS Station 03170000), and precipitation (Stations 443071/449169/441692) data.**

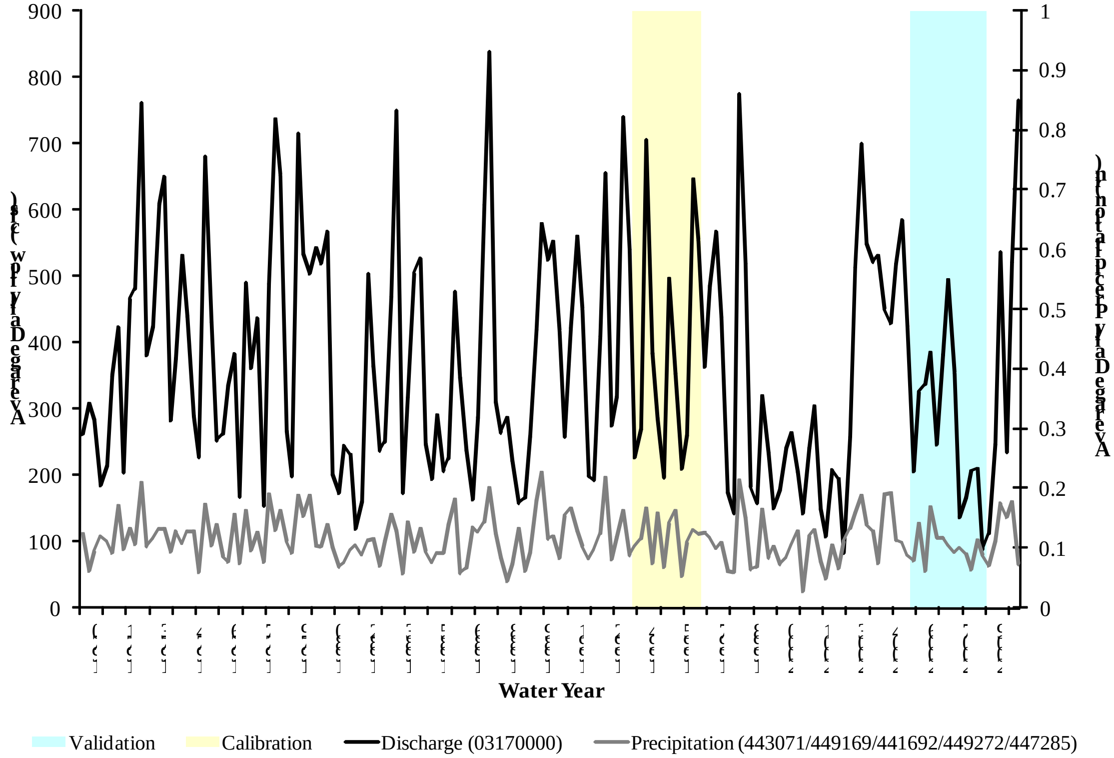

Figure B. 5 Modeling time periods, seasonal historical flow (USGS Station 03170000), and precipitation (Stations 443071/449169/441692) data.

Table B. 5 Comparison of modeled period to historical records for the Little River.

	Discharge (03170000)				Precipitation (443071/449169/441692)			
	Fall	**Winter**	**Spring**	**Summer**	**Fall**	**Winter**	**Spring**	**Summer**
	Historical Record (1928 - 2010)				**Historical Record (1933 - 2010)**			
Mean	300	469	424	243	0.105	0.114	0.124	0.120
Variance	16,383	21,736	25,436	15,494	0.001	0.001	0.002	0.002
	Calibration and Validation Time Periods (10/93-9/96; 10/05-9/08)				**Calibration and Validation Time Periods (10/93-9/97; 10/05-9/09)**			
Mean	266	481	373	221	0.107	0.111	0.122	0.107
Variance	6,272	34,862	12,049	10,090	0.001	0.0018	0.001	0.001
	p-values				**p-values**			
Mean	0.178	0.444	0.153	0.308	0.427	0.450	0.467	0.197
Variance	0.141	0.173	0.206	0.338	0.224	0.194	0.497	0.405

Bacteria TMDL Critical Condition

EPA regulations at 40 CFR 130.7 (c)(1) require that TMDLs take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the Little River study area is protected during times when it is most vulnerable.

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken in order to meet water quality standards. Fecal bacteria sources within the Little River study area are attributed to both point and nonpoint sources. Critical conditions for waters impacted by land-based nonpoint sources generally occur during periods of wet weather and high surface runoff. In contrast, critical conditions for point source-dominated systems generally occur during low flow and low dilution conditions. Point sources, in this context also, include nonpoint sources that are not precipitation driven (*e.g.*, fecal deposition to stream).

A description of the data used in these analyses is shown in Tables 2.1 and 2.2 in Chapter 2. Graphical analyses of fecal bacteria concentrations and flow duration intervals showed that water quality standard violations occurred at nearly every flow interval at 14 VADEQ monitoring stations in the Little River watershed (Figures B.6 - Figure B.19). This demonstrates that this stream should have all flow regimes represented in the allocation modeling time period. Therefore, to account for critical conditions for bacteria in the watershed, the allocation modeling period is selected to coincide with the hydrologic calibration period since the later was selected to include both low and high flow conditions.

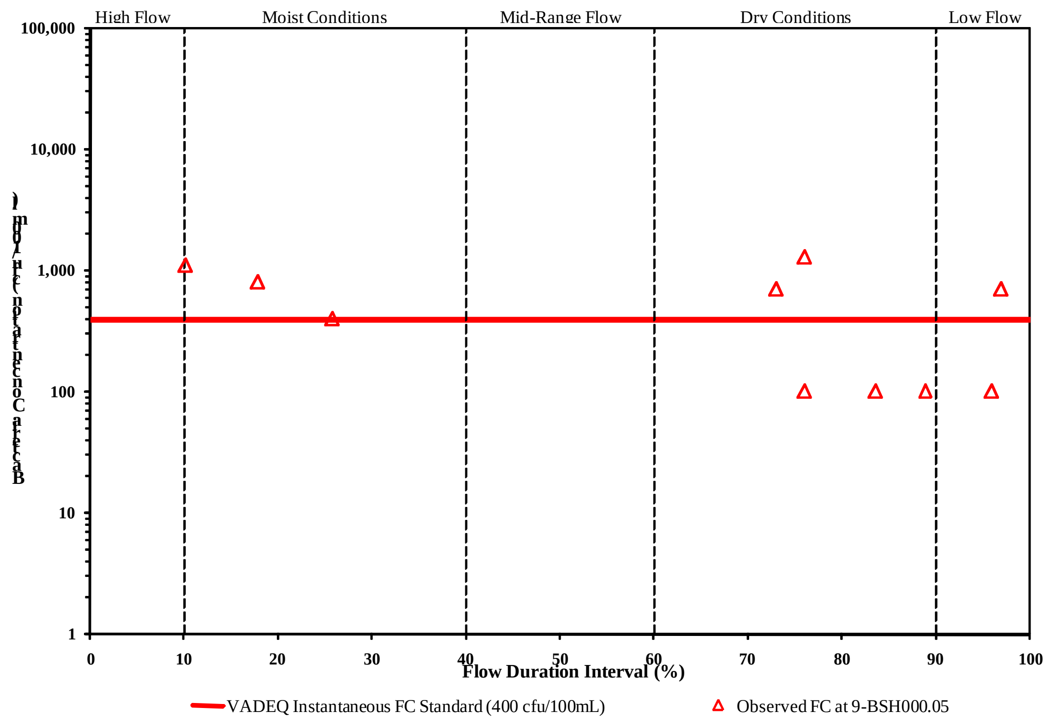

Figure B. 6 Fecal coliform concentrations at 9-BSH000.05 on Bush Creek versus discharge at USGS Gaging Station #03170000.

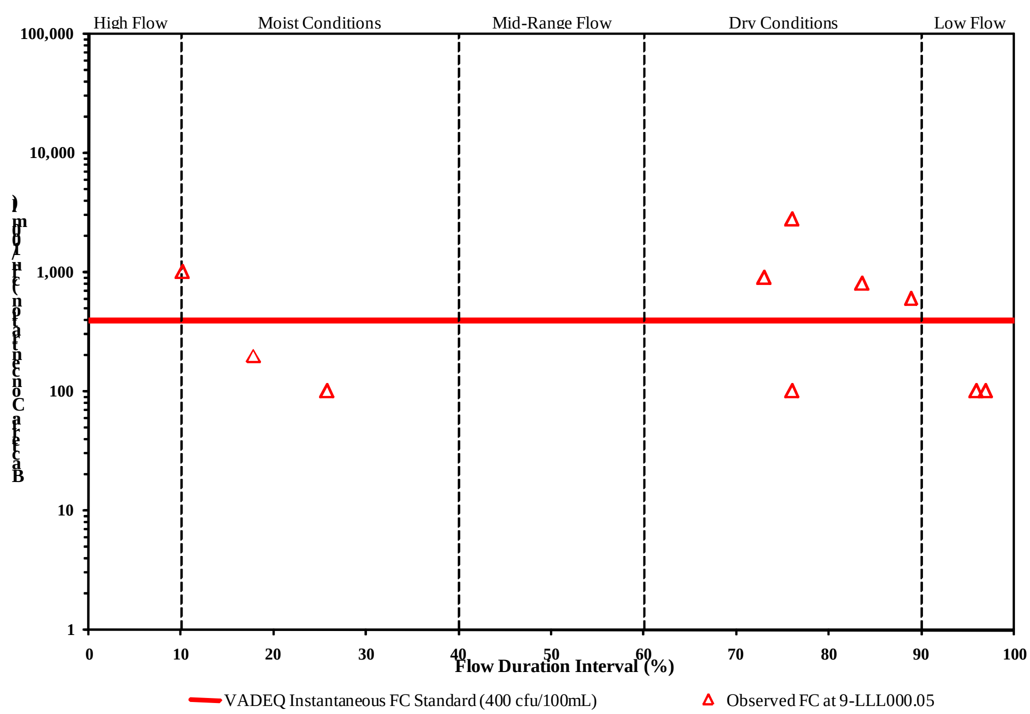

Figure B. 7 Fecal bacteria concentrations at 9-LLL000.05 on Laurel Creek versus discharge at USGS Gaging Station #03170000.

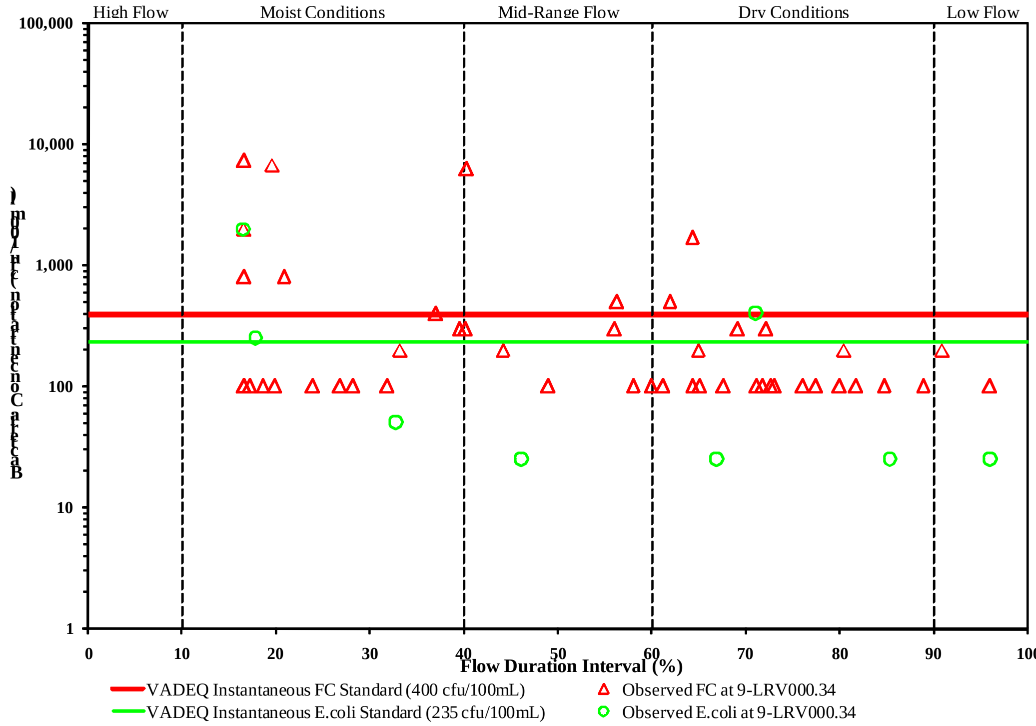

Figure B. 8 Fecal bacteria and *E.coli* concentrations at 9-LRV000.34 on the Little River versus discharge at USGS Gaging Station #03170000.

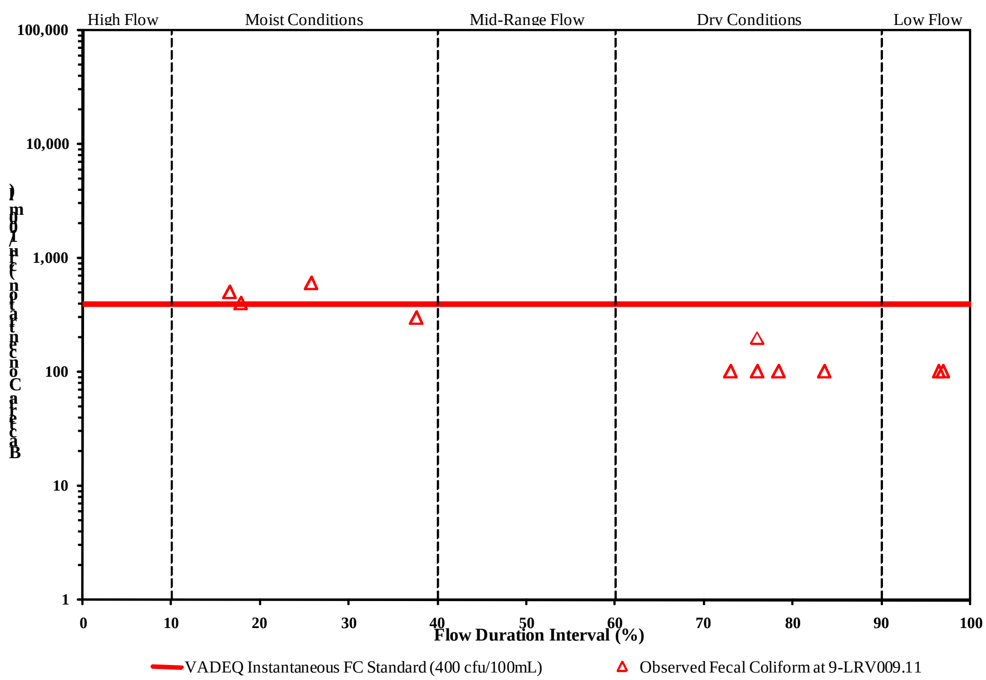

Figure B. 9 Fecal bacteria concentrations at 9-LRV009.11 on the Little River versus discharge at USGS Gaging Station #03170000.

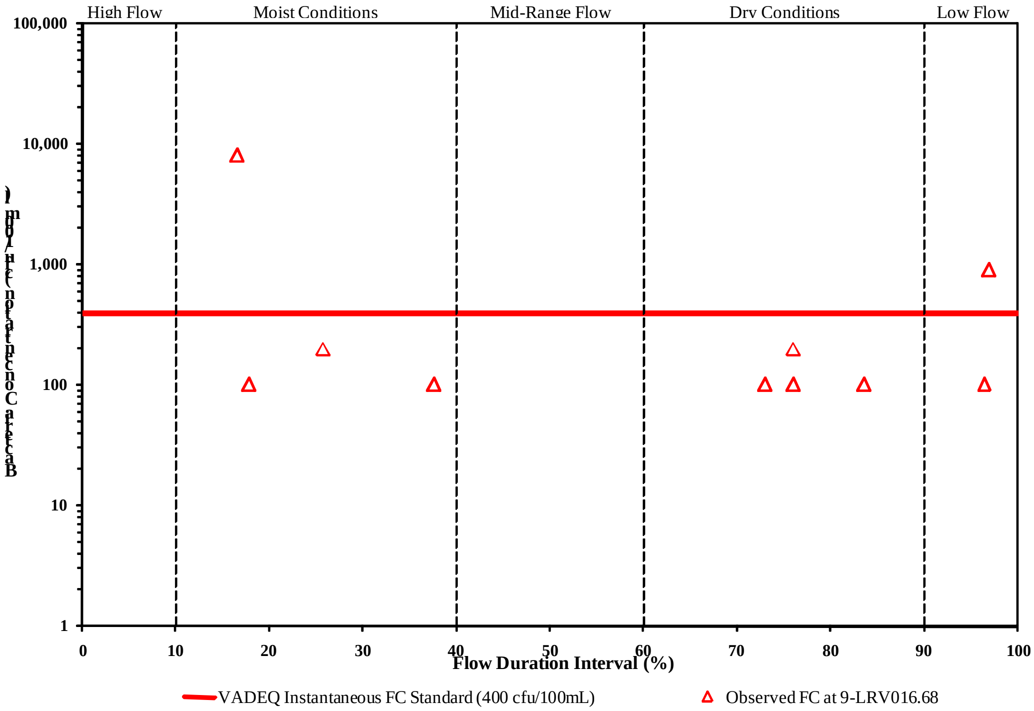

Figure B. 10 Fecal bacteria concentrations at 9-LRV016.6 on the Little River versus discharge at USGS Station #03170000.

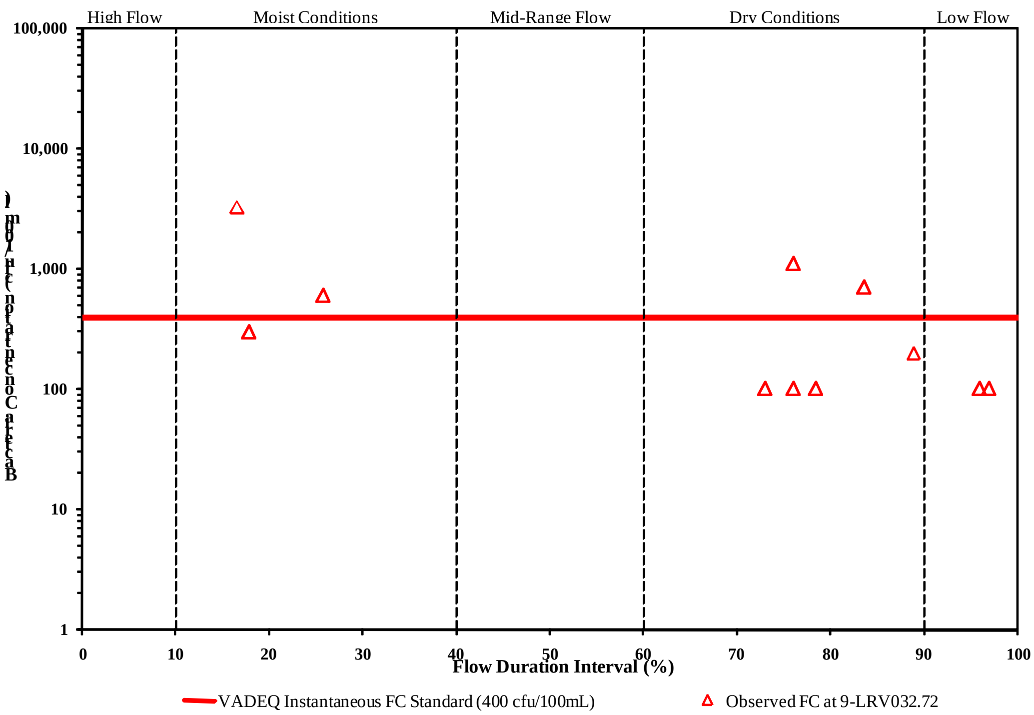

Figure B. 11 Fecal bacteria concentrations at 9-LRV032.72 on the Little River versus discharge at USGS Station #03170000.

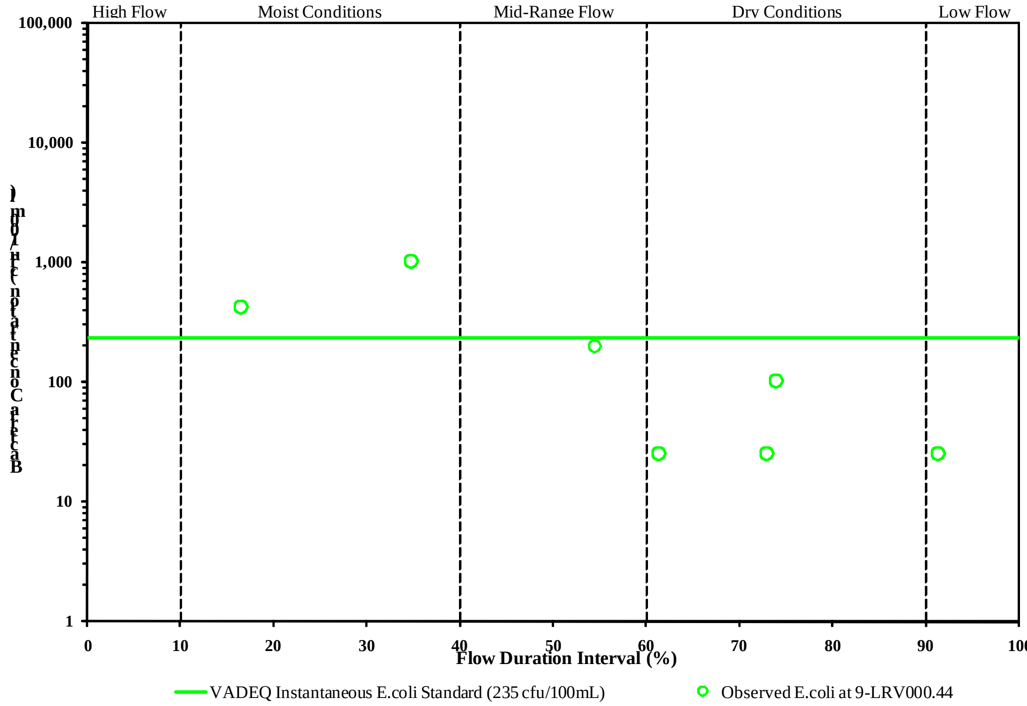

Figure B. 12 *E.coli* bacteria concentrations at 9-LRV000.44 on the Little River versus discharge at USGS Gaging Station #03170000.

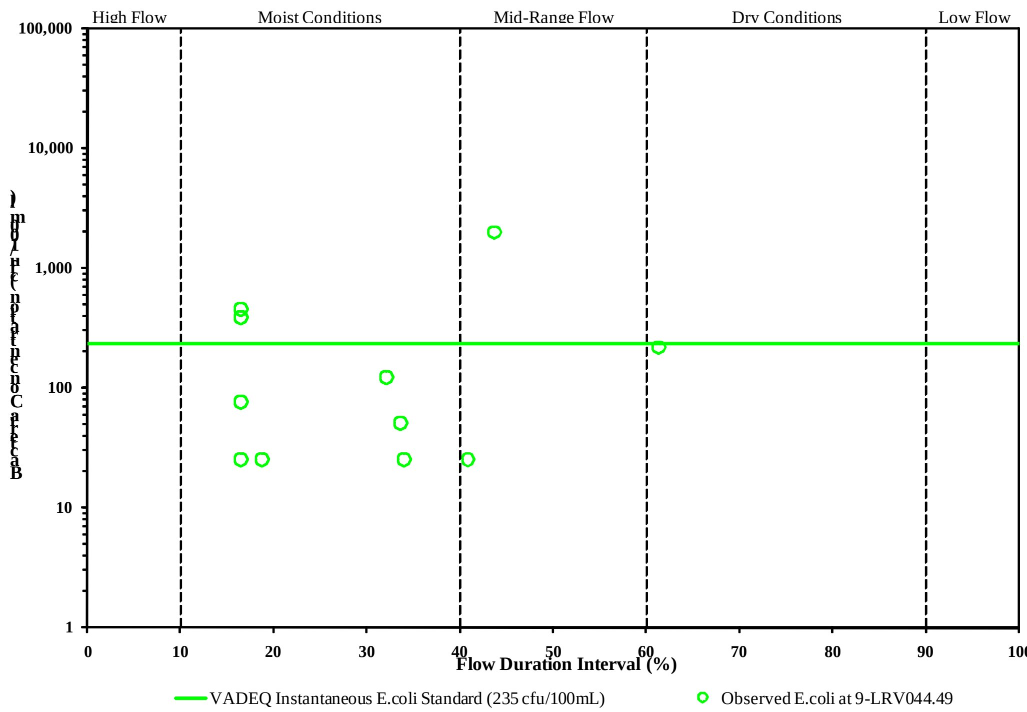

Figure B. 13 *E.coli* bacteria concentrations at 9-LRV044.49 on the Little River versus discharge at USGS Gaging Station #03170000.

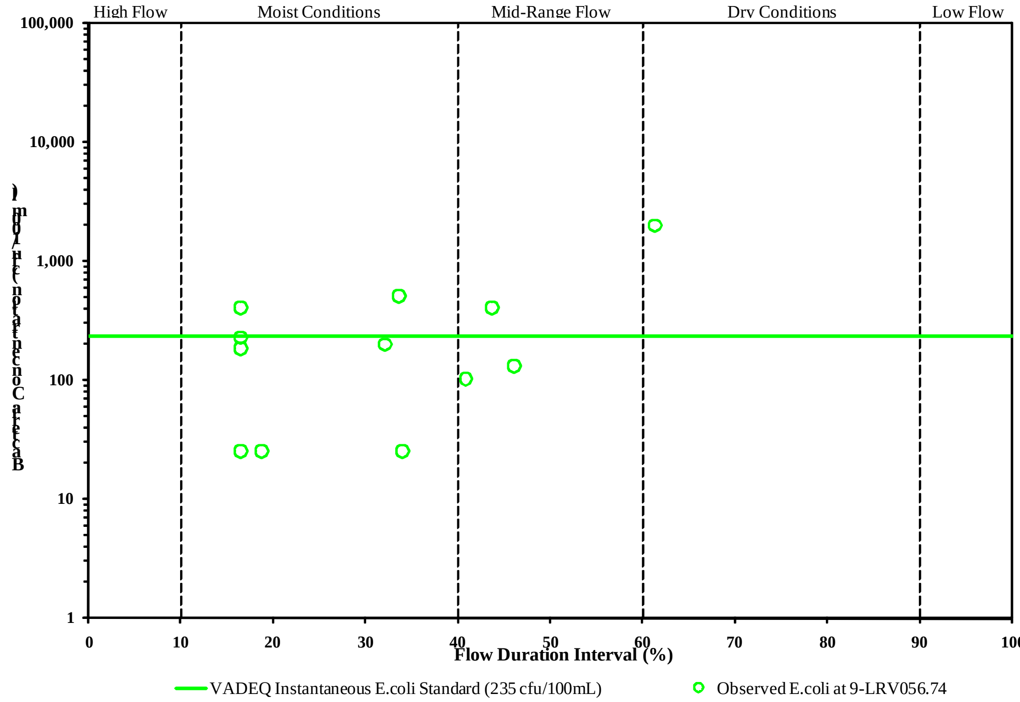

Figure B. 14 ***E.coli*** **bacteria concentrations at 9-LRV056.74 on the Little River versus discharge at USGS Gaging Station #03170000.**

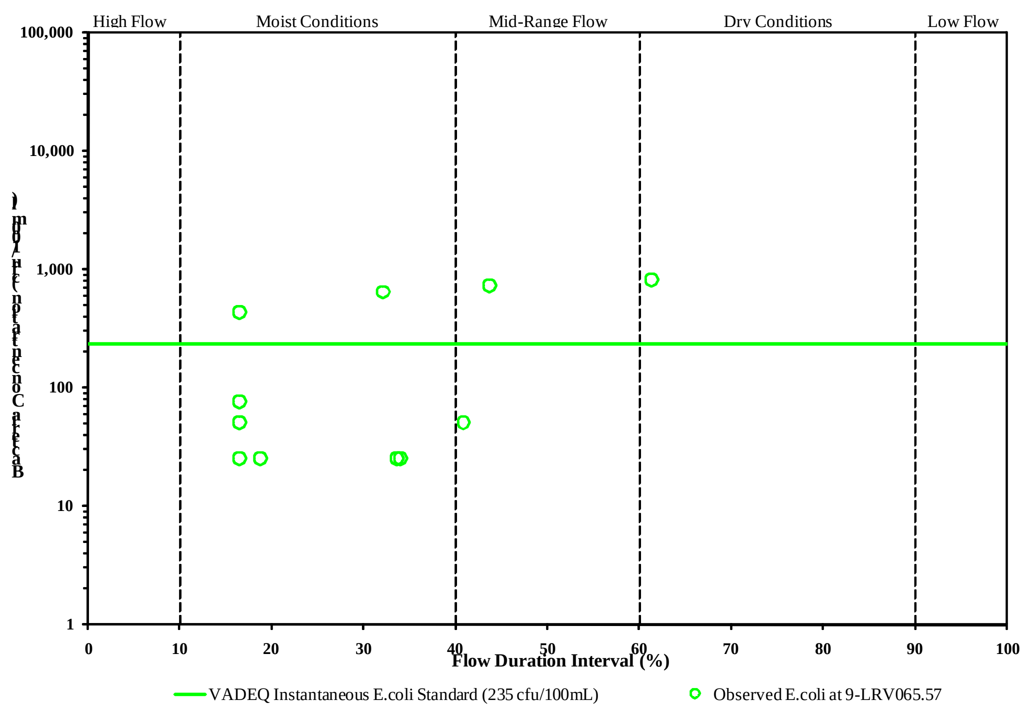

Figure B. 15 ***E.coli*** **bacteria concentrations at 9-LRV065.57 on the Little River versus discharge at USGS Gaging Station #03170000.**

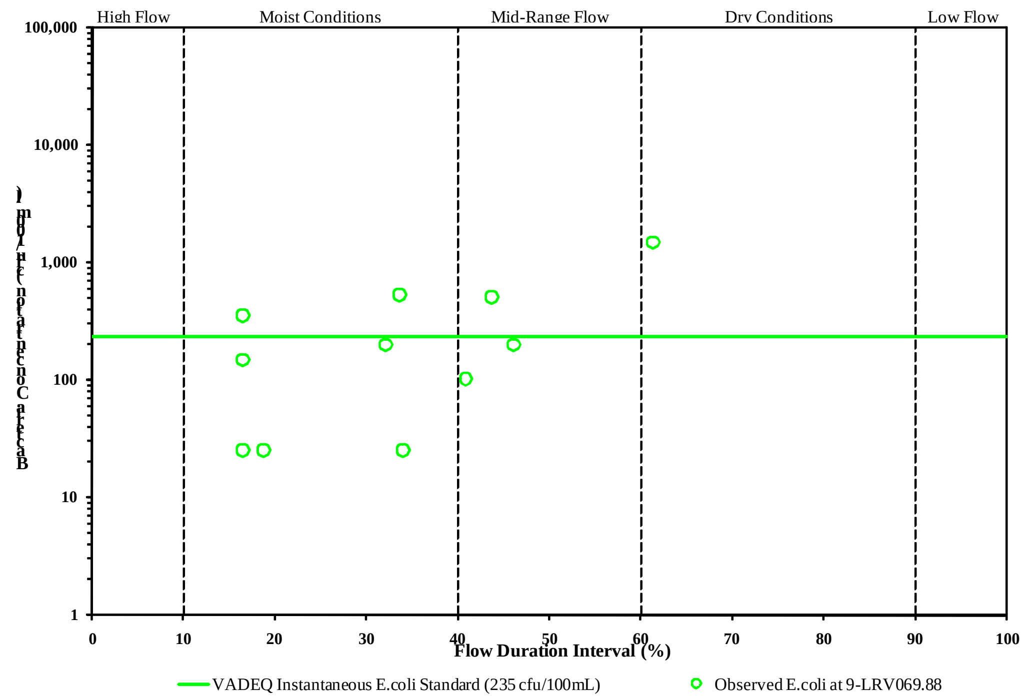

Figure B. 16 ***E.coli* bacteria concentrations at 9-LRV069.88 on the Little River versus discharge at USGS Gaging Station #03170000.**

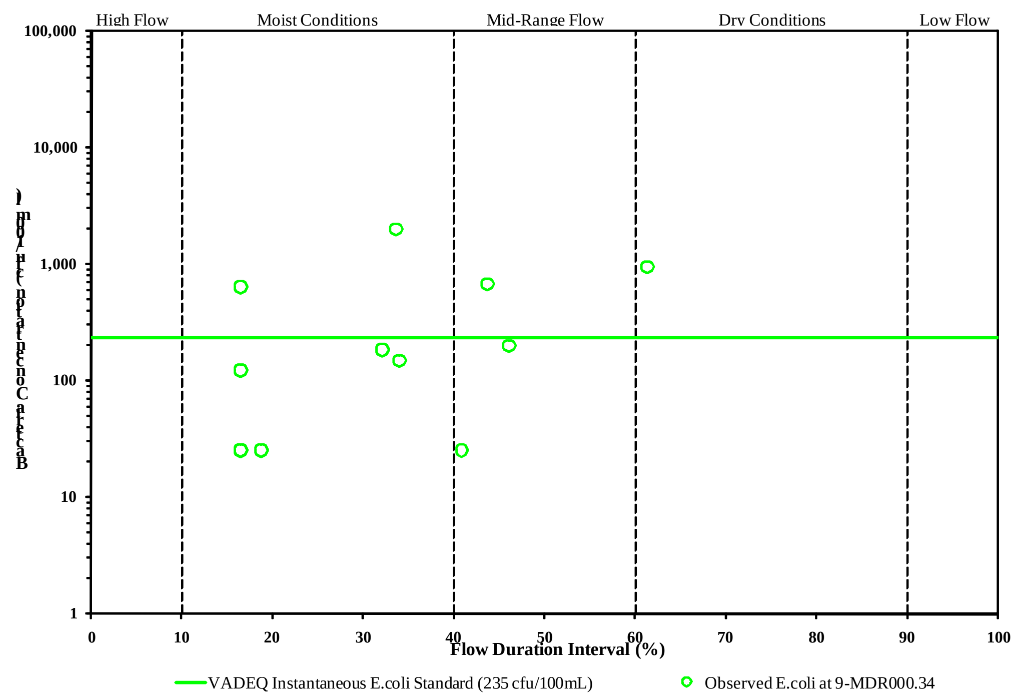

Figure B. 17 ***E.coli* bacteria concentrations at 9-MDR000.34 on Meadow Run versus discharge at USGS Gaging Station #03170000.**

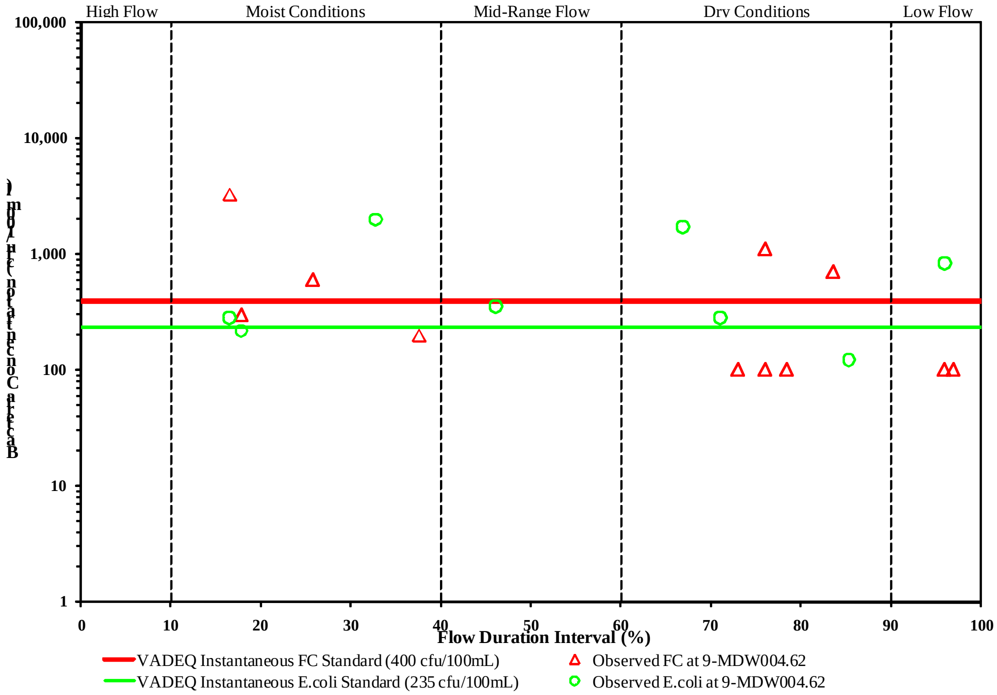

Figure B. 18 Fecal and *E.coli* bacteria concentrations at 9-MDW004.62 on Meadow Creek versus discharge at USGS Gaging Station #03170000.

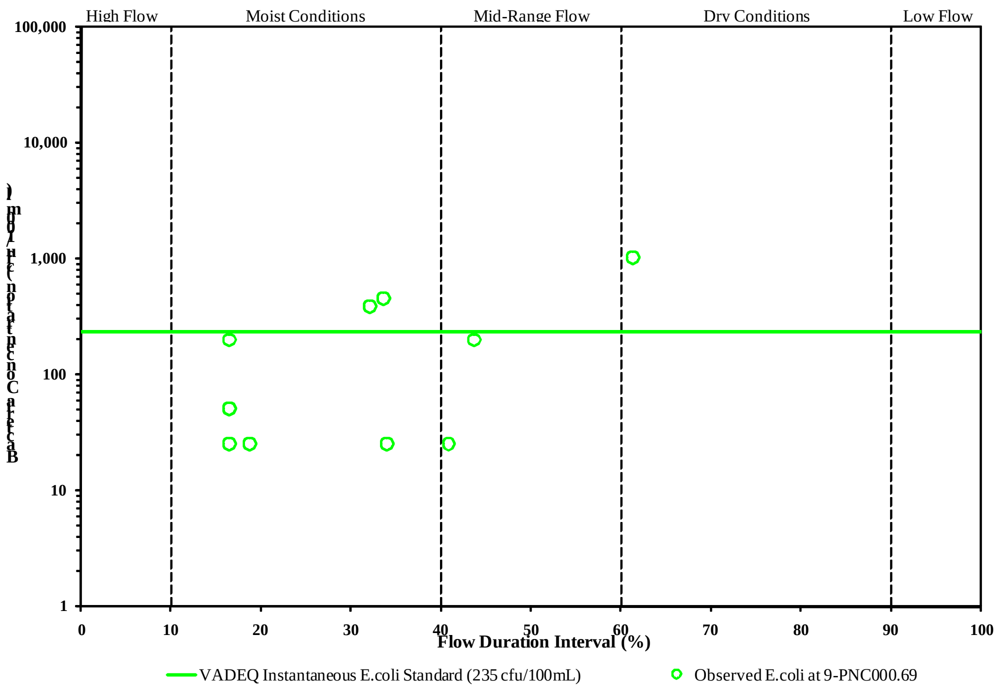

Figure B. 19 *E.coli* bacteria concentrations at 9-PNC000.69 on Pine Creek versus discharge at USGS Gaging Station #03170000.

Source Representation

Both point and nonpoint sources can be represented in the model. In general, point sources are added to the model as a time-series of pollutant and flow inputs to the stream. Land-based nonpoint sources are represented as an accumulation of pollutants on land, where some portion is available for transport in runoff. The amount of accumulation and availability for transport vary with land use type and season. The model allows for a maximum accumulation to be specified. The maximum accumulation was adjusted seasonally to account for changes in die-off rates, which are dependent on temperature and moisture conditions. Some nonpoint sources, rather than being land-based, are represented as being deposited directly to the stream (*e.g.,* animal defecation in stream). These sources are modeled similarly to point sources, as they do not require a runoff event for delivery to the stream. These sources are primarily due to animal activity, which varies with the time of day. Once in stream, die-off is represented by a first-order exponential equation.

Much of the data used to develop the model inputs for modeling water quality is time-dependent (*e.g.,* population). Depending on the timeframe of the simulation being run, different estimates were used. Data were obtained for the appropriate timeframe for water quality calibration and validation. Data representing 2011 were used for the allocation runs in order to represent current conditions.

Permitted Sources

Four domestic permits exist within the watershed (outside of the areas covered in Mill and Dodd Creeks TMDLs) which are permitted to discharge water into surface waters in the Little River study area. These sources are permitted through the Virginia Pollutant Discharge Elimination System (VPDES) (Table 3.1). During quality modeling effort, these permits were assigned a maximum design flow of 1,000 gallons per day. This flow rate was combined with a fecal coliform concentration of 200 cfu/100 mL to ensure that compliance with state water quality standards could be met even if permitted loads were at maximum levels (Table B.6).

Nonpoint sources of pollution that were not driven by runoff (*e.g.*, direct deposition of fecal matter to the the stream by wildlife) were modeled similarly to point sources. These sources, as well as land-based sources, are identified in the following sections.

Table B. 6 Flow rates and bacteria loads used to model VADEQ active permits in the Little River study area.

VADEQ Permit Number	Facility Name	Calibration/Validation: Flow Rate (Gallon per Day)	Calibration/Validation: Bacteria Concentration (cfu/100 mL) Fecal Coliform Geometric Mean Standard	Allocation: Flow Rate (Gallon per Day)	Allocation: Bacteria Concentration (cfu/100mL) Fecal Coliform Geometric Mean Standard
VAG402090	Domestic	450	200	1000	200
VAG402042	Domestic	150	200	1000	200
VAG402051	Domestic	100	200	1000	200
VAG402018	Domestic	300	200	1000	200

Private Residential Sewage Treatment

The number of septic systems in the Little River study area was calculated by overlaying U.S. Census Bureau data (USCB, 1990; USCB, 2000) with the subwatersheds. During allocation runs, the number of households was projected to 2011, based on current growth rates (USCB, 2000) resulting in 6,265 septic systems and 357 straight pipes (Table B.7).

Table B. 7 Estimated failing septic systems and straight pipes for 2011 in the Little River study area.

Watershed	Septic Systems	Failing Septic Systems	Straight Pipes
Little River	6,265	1,096	357

Failing septic systems were assumed to deliver all effluent to the soil surface where it was available for wash-off during a runoff event. In accordance with estimates from Raymond B. Reneau, Jr. from Virginia Tech, a 40% failure rate for systems designed and installed prior to 1964, a 20% failure rate for systems designed and installed between 1964 and 1984, and a 5% failure rate on all systems designed and installed after 1984 was used in development of the TMDLs for the Little River study area. Total septic systems in each category were calculated using U.S. Census Bureau block demographics. The applicable failure rate was multiplied by each total and summed to get the total failing septic systems per subwatershed. The fecal coliform density for septic system effluent was multiplied by the average design load for the septic systems in the subwatershed to determine the total load from each failing system. Additionally, the loads were distributed seasonally based on a survey of septic pump-out contractors to account for more frequent failures during wet months.

Straight pipes were estimated using 1990 U.S. Census Bureau block demographics. Houses listed in the Census sewage disposal category “other means” were assumed to be disposing sewage via straight pipes. Corresponding block data and subwatershed boundaries were intersected to determine an estimate of uncontrolled discharges in each subwatershed. The loadings from straight pipes were modeled in the same manner as direct discharges to the stream.

Livestock

Fecal coliform produced by livestock can enter surface waters through four pathways: land application of stored waste, deposition on land, direct deposition to streams, and diversion of wash-water and waste directly to streams. Each of these pathways is accounted for in the model. The amount of fecal coliform directed through each pathway was calculated by multiplying the fecal coliform density with the amount of waste expected through that pathway. Different livestock populations were estimated for each water quality modeling period (calibration/validation/allocation). The numbers are based on data provided by Virginia Agricultural Statistics (VASS), with values updated and discussed by VADCR, NRCS and SWCDs as well as taking into account growth rates in these counties as determined from data reported by the Virginia Agricultural Statistics Service (VASS, 1998; VASS, 2002). For land-applied waste, the fecal coliform density measured from stored waste was used, while the density in as-excreted manure was used to calculate the load for deposition on land and to streams. The use of fecal coliform densities measured in stored manure accounts for any die-off that occurs in storage. The modeling of fecal coliform entering the stream through diversion of wash-water was accounted for by the direct deposition of fecal matter to streams by cattle.

Land Application of Collected Manure

Collection of livestock manure was assumed the case on dairy farms. The average daily waste production per month was calculated using the number of animal units, weight of animal, and waste production rate as reported in Section 3.2.4. Second, the total amount of waste produced in confinement was calculated based on the proportion of time spent in confinement. Finally, values for the percentage of loafing lot waste collected, based on data provided by SWCD representatives and local stakeholders, were used to calculate the amount of waste available to be spread on pasture and cropland (Table 3.8). Stored waste was spread on pasture and cropland. It was assumed that 100% of land-applied waste is available for transport in surface runoff.

Deposition on Land

For cattle, the amount of waste deposited on land per day was a proportion of the total waste produced per day. The proportion was calculated based on the study entitled "Modeling Cattle Stream Access" conducted by the Biological Systems Engineering Department at Virginia Tech and MapTech, Inc. for VADCR (MapTech, 2002). The proportion was based on the amount of time spent in pasture, but not in close proximity to accessible streams, and was calculated as follows:

Proportion = [(24 hr) – (time in confinement) – (time in stream access areas)]/(24 hr)

All other livestock (horses, sheep) were assumed to deposit all feces on pasture. The total amount of fecal matter deposited on the pasture land was area-weighted.

Direct Deposition to Streams

The amount of waste deposited in streams each day was a proportion of the total waste produced per day by cattle. First, the proportion of manure deposited in "stream access" areas was calculated based on the "Modeling Cattle Stream Access" study. The proportion was calculated as follows:

Proportion = (time in stream access areas)/(24 hr)

For the waste produced on the "stream access" land use, 30% of the waste was modeled as being directly deposited in the stream and 70% remained on the land segment adjacent to the stream. The 70% remaining was treated as manure deposited on land. However, applying it in a separate land-use area (stream access) allows the model to consider the proximity of the deposition to the stream. The 30% that was directly deposited to the stream was modeled in the same way that point sources are handled in the model.

Biosolids

Investigation of VADEQ data indicated that biosolids applications have occurred within the Little River study area. Class B biosolids are permitted to contain up to 1,995,262 cfu/g-dry, as compared with approximately 240 cfu/g-dry for dairy waste. Records of biosolids application location, timing and quantity were available, enabling the water quality modeling to be carried out in an "as applied" fashion, wherein the water quality model received land based inputs of biosolids loads on the day in which they actually occurred. During model runs, biosolids were modeled as having a fecal concentration of 157,835 cfu/g, the mean value of measured biosolids concentrations observed in several years of samples supplied by VADEQ for sources applied during 2002 to 2010. Applications were modeled as being spread onto the land surface over a six-hour period on the date of reported application. An assumption of proper application was made, wherein no biosolids were modeled as being spread in stream corridors.

Wildlife

For each species of wildlife, a GIS habitat layer was developed based on the habitat descriptions that were obtained (Section 3.2.5). An example of one of these layers is shown in Figure B.20. This layer was overlaid with the land use layer and the resulting area was calculated for each land use in each subwatershed. The number of animals per land segment was determined by multiplying the area by the population density. Fecal coliform loads for each land segment were calculated by multiplying the wasteload, fecal coliform densities, and number of animals for each species.

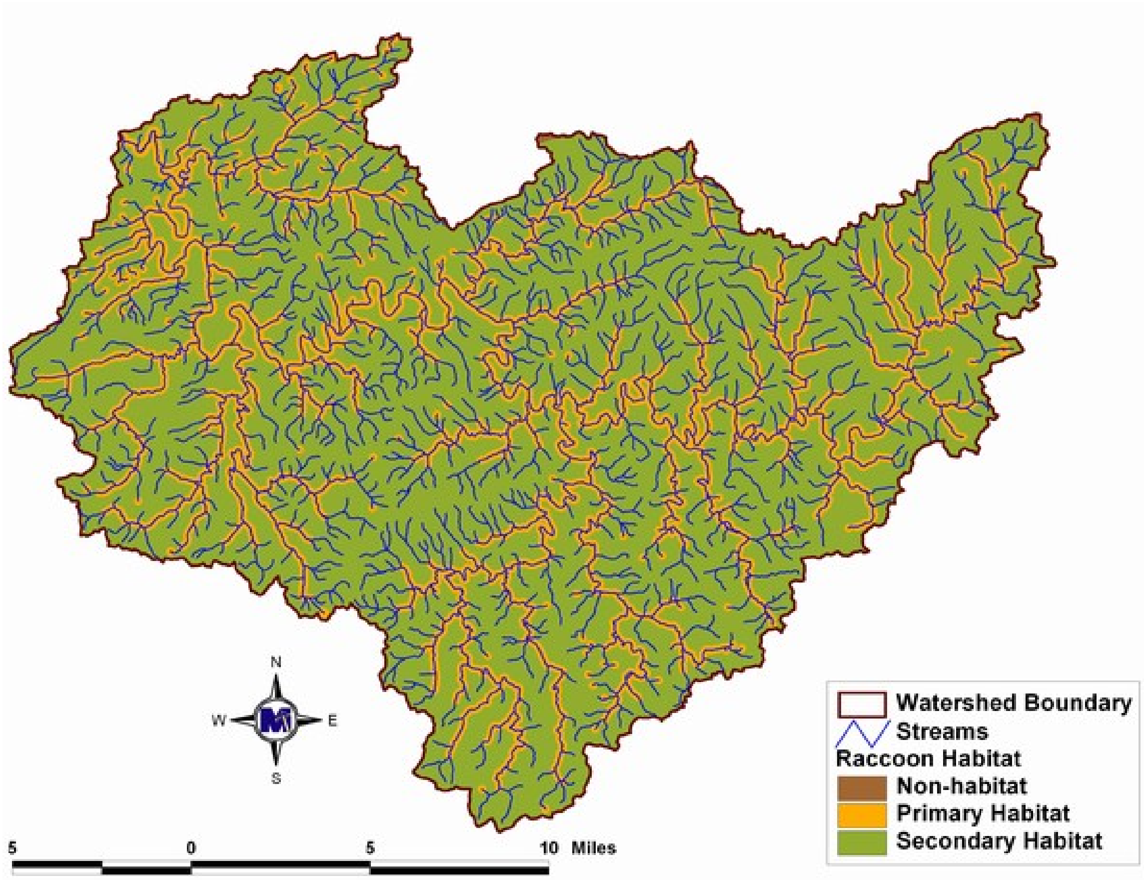

Figure B. 20 Example of raccoon habitat layer in the Little River study area, as developed by MapTech.

For each species, a portion of the total wasteload was considered land-based, with the remaining portion being directly deposited to streams. The portion being deposited to streams was based on the amount of time spent in stream access areas (Table 3.12). It was estimated that, for all animals other than beaver, 5% of fecal matter produced while in stream access areas was directly deposited to the stream. For beaver, it was estimated that 100% of fecal matter would be directly deposited to streams.

Pets

Cats and dogs were the only pets considered in this analysis. Population density (animals per house), wasteload, and fecal coliform density are reported in Section 3.2.3. Waste from pets was distributed on residential land uses. The number of households per subwatershed was taken from the 2000 Census (USCB, 1990 and USCB, 2000). The number of animals per subwatershed was determined by multiplying the number of households by the pet population density. The amount of fecal coliform deposited daily by pets in each subwatershed was calculated by multiplying the wasteload, fecal coliform density, and number of animals for both cats and dogs. The wasteload was assumed not to vary seasonally. The populations of cats and dogs were projected from 2000 data to 2011.

Sensitivity Analysis

Sensitivity analyses are performed to determine a model's response to changes in certain parameters. This process involves changing a single parameter a certain percentage from a baseline value while holding all other parameters constant. This process is repeated for several parameters in order to gain a complete picture of the model's behavior. The information gained during sensitivity analysis can aid in model calibration, and it can also help to determine the potential effects of uncertainty in parameter estimation. Sensitivity analyses were conducted to assess the sensitivity of the model to changes in hydrologic and water quality parameters as well as to assess the impact of unknown variability in source allocation (*e.g.*, seasonal and spatial variability of waste production rates for wildlife, livestock, septic system failures, uncontrolled discharges, background loads, and point source loads).

Hydrology Sensitivity Analysis

The HSPF parameters adjusted for the hydrologic sensitivity analysis are presented in Table B.8, with base values for the model runs given. The parameters were adjusted to -50%, -10%, 10%, and 50% of the base value, and the model was run for water years 1993-1996. Where an increase of 50% exceeded the maximum value for the parameters, the maximum value was used and the parameters increased over the base value were reported. The hydrologic quantities of greatest interest in a fecal coliform model are those that govern peak flows and low flows. Peak flows, being a function of runoff, are important because they are directly related to the transport of fecal coliforms from the land surface to the stream. Peak flows were most sensitive to changes in the parameters governing infiltration such as INFILT (Infiltration), LZSN (Lower Zone Storage), and by UZSN (Upper Zone Storage), which governs surface transport, LZETP (Lower Zone Evapotranspiration), which affects soil moisture and AGWRC (Groundwater Recession

Rate). Low flows are important in a water quality model because they control the level of dilution during dry periods. Parameters with the greatest influence on low flows (as evidenced by their influence in the *Low Flows* and *Summer Flow Volume* statistics) were AGWRC (Groundwater Recession Rate), BASETP (Base Flow Evapotranspiration), LZETP, INFILT, UZSN, CEPSC (Interception Storage Capacity), and LZSN. The responses of these and other hydrologic outputs are reported in Table B.9.

Table B. 8 HSPF base parameter values used to determine hydrologic model response.

Parameter	Description	Units	Base Value
LZSN	Lower Zone Nominal Storage	in	4.0
INFILT	Soil Infiltration Capacity	in/hr	0.0398 – 0.2136
BASETP	Base Flow Evapotranspiration	---	0.02 - 0.02
INTFW	Interflow Inflow	---	2.0 - 2.0
DEEPFR	Groundwater Inflow to Deep Recharge	---	0.06 - 0.06
AGWRC	Groundwater Recession rate	---	0.94
KVARY	Groundwater Recession Flow	1/in	1.0
MON-INTERCEP	Monthly Interception Storage Capacity	in	0.01-0.2
MON-UZSN	Monthly Upper Zone Nominal Storage	in	0.60-1.5
MON-LZETP	Monthly Lower Zone Evapotranspiration	in	0.01-0.40

Table B. 9 HSPF Sensitivity analysis results for hydrologic model parameters for the Little River Watershed.

Model Parameter	Parameter Change (%)	Total Flow	High Flows	Low Flows	Winter Flow Volume	Spring Flow Volume	Summer Flow Volume	Fall Flow Volume	Total Storm Volume
		Percent Change In							
AGWRC[1]	0.85	0.40	10.94	-41.17	0.38	0.62	-4.11	3.30	0.45
AGWRC[1]	0.92	0.13	3.21	-13.95	-0.09	0.29	-1.59	1.71	0.17
AGWRC[1]	0.96	-0.25	-3.96	19.80	0.51	-0.68	2.37	-3.69	-1.06
AGWRC[1]	0.999	-16.70	-22.74	92.48	-22.08	-2.86	-0.03	-26.61	-26.58
BASETP	-50	0.91	-0.51	11.11	-0.02	2.24	4.01	0.07	0.61
BASETP	-10	0.17	-0.10	2.06	0.00	0.40	0.75	0.02	0.21
BASETP	10	-0.18	0.10	-2.22	0.00	-0.47	-0.76	-0.02	-0.14
BASETP	50	-0.85	0.48	-10.32	0.01	-2.14	-3.62	-0.10	-0.80
DEEPFR	-50	1.97	1.39	2.62	1.63	2.06	2.57	2.38	2.01
DEEPFR	-10	0.39	0.28	0.45	0.33	0.38	0.51	0.48	0.43
DEEPFR	10	-0.40	-0.28	-0.65	-0.33	-0.46	-0.53	-0.48	-0.36
DEEPFR	50	-1.98	-1.38	-2.85	-1.63	-2.13	-2.60	-2.38	-1.94
INFILT	-50	-1.57	9.13	-22.38	2.21	-4.69	-10.55	-2.80	-1.52
INFILT	-10	-0.32	1.20	-3.69	0.35	-0.88	-1.90	-0.53	-0.27
INFILT	10	0.30	-1.02	3.18	-0.32	0.78	1.78	0.53	0.34
INFILT	50	1.46	-3.82	13.80	-1.41	3.90	7.99	2.52	1.49
INTFW	-50	-0.08	1.60	-1.01	0.28	-0.47	-0.92	-0.09	-0.03
INTFW	-10	-0.02	0.22	-0.23	0.04	-0.08	-0.18	-0.01	0.03
INTFW	10	0.00	-0.20	0.00	-0.04	-0.01	0.14	0.01	0.04
INTFW	50	0.02	-0.76	0.28	-0.17	0.11	0.61	0.04	0.06
LZSN	-50	4.57	10.95	-10.22	7.33	-1.42	-9.68	12.42	4.62
LZSN	-10	0.64	1.58	-1.56	1.25	-0.09	-1.95	1.42	0.68
LZSN	10	-0.56	-1.36	1.24	-1.16	-0.04	1.82	-1.02	-0.52
LZSN	50	-2.18	-5.37	5.62	-5.03	-0.36	7.63	-2.79	-2.14
CEPSC	-50	3.25	1.09	14.00	0.61	8.65	6.07	3.33	3.27
CEPSC	-10	0.56	0.19	2.43	0.14	1.49	1.30	0.32	0.60
CEPSC	10	-0.54	-0.20	-2.34	-0.15	-1.41	-1.17	-0.34	-0.50
CEPSC	50	-2.66	-0.96	-11.04	-0.65	-6.46	-4.95	-2.91	-2.61
LZETP	-50	13.57	15.35	18.00	5.17	3.15	30.88	34.81	13.62
LZETP	-10	2.75	2.55	4.61	0.85	0.80	7.66	6.48	2.79
LZETP	10	-2.71	-2.34	-5.13	-0.82	-0.96	-7.81	-6.09	-2.67
LZETP	50	-10.85	-8.93	-23.03	-3.42	-4.57	-29.45	-24.58	-10.81
KVARY	-50	-0.19	-4.20	18.69	0.16	0.01	1.98	-2.77	-0.48
KVARY	-10	-0.04	-0.74	2.97	0.02	-0.05	0.34	-0.43	0.00
KVARY	10	0.02	0.69	-2.91	-0.01	-0.02	-0.34	0.38	0.06
KVARY	50	0.11	3.13	-12.14	-0.02	0.02	-1.40	1.54	0.15
UZSN	-50	7.64	14.09	-5.15	4.88	8.23	8.07	14.27	7.68
UZSN	-10	1.17	2.25	-1.07	0.91	0.82	1.10	2.28	1.22
UZSN	10	-1.11	-2.10	0.82	-0.85	-0.78	-1.12	-2.12	-1.07
UZSN	50	-4.66	-8.76	4.12	-5.03	-1.76	-4.34	-6.66	-4.62

[1]Actual parameter value used

Water Quality Parameter Sensitivity Analysis

For the water quality sensitivity analysis, an initial base run was performed using precipitation data from water years 1994 through 1996, and model parameters established for 2011 conditions. The three HSPF parameters impacting the model's water quality response (Table B.10) were increased and decreased by amounts that were consistent with the range of values for the parameter. The First Order Decay (FSTDEC) was the parameter with the greatest influence on monthly geometric mean concentration (Table B.11). The reason behind the more pronounced impact of change in decay rate on concentration of bacteria in the stream is that changes in decay rate impact bacteria from nonpoint as well as point sources and direct-nonpoint sources. On the other hand, changes in maximum fecal coliform accumulation on the land (MON-SQOLIM) and wash-off rate for fecal coliform on land surface (WSQOP) only impact the nonpoint portion of the bacteria. Graphical depictions of the results of this sensitivity analysis can be seen in Figures B.21 through B.23.

Table B. 10 Base parameter values used to determine water quality model response.

Parameter	Description	Units	Base Value
MON-SQOLIM	Maximum FC Accumulation on Land	FC/ac	0 – 9.5E+12
WSQOP	Wash-off Rate for FC on Land Surface	in/hr	0.4 – 1.4
FSTDEC	In-stream First Order Decay Rate	1/day	9

Table B. 11 Percent change in average monthly *E.coli* mean for the years 1994-1996.

Model Parameter	Parameter Change (%)	Percent Change in Average Monthly *E. coli* Geometric Mean for 1994-1996 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
FSTDEC	-50	67.93	70.56	71.39	71.12	68.41	69.91	70.18	69.97	71.23	72.82	67.77	69.89
FSTDEC	-10	9.26	9.51	9.53	9.70	9.32	9.46	9.65	9.54	9.77	9.95	9.33	9.53
FSTDEC	10	-8.02	-8.21	-8.19	-8.38	-8.07	-8.17	-8.35	-8.25	-8.45	-8.59	-8.09	-8.24
FSTDEC	50	-31.75	-32.27	-32.12	-32.96	-31.90	-32.19	-32.95	-32.50	-33.25	-33.71	-32.05	-32.44
SQOLIM	-50	-27.96	-18.91	-20.80	-10.84	-22.88	-18.71	-11.63	-14.85	-11.72	-12.16	-26.93	-23.02
SQOLIM	-25	-13.54	-8.29	-9.44	-4.68	-10.70	-9.74	-6.49	-7.97	-6.09	-6.35	-14.00	-11.72
SQOLIM	25	12.78	6.64	7.43	3.55	8.56	7.35	4.75	6.38	5.41	5.93	14.20	11.44
SQOLIM	50	20.62	10.18	11.97	5.91	14.99	14.43	10.06	12.95	10.01	10.48	24.54	19.11
WSQOP	-50	33.05	23.71	22.57	26.44	29.44	19.17	20.09	15.12	19.58	19.63	37.27	31.93
WSQOP	-10	4.48	3.23	3.08	3.02	3.92	2.63	2.32	2.00	2.32	2.31	4.64	3.94
WSQOP	10	-4.47	-3.25	-3.13	-2.88	-3.92	-2.65	-2.22	-1.99	-2.23	-2.22	-4.54	-3.84
WSQOP	50	-17.08	-12.69	-12.29	-10.33	-14.94	-10.36	-7.98	-7.67	-8.07	-8.03	-16.77	-14.21

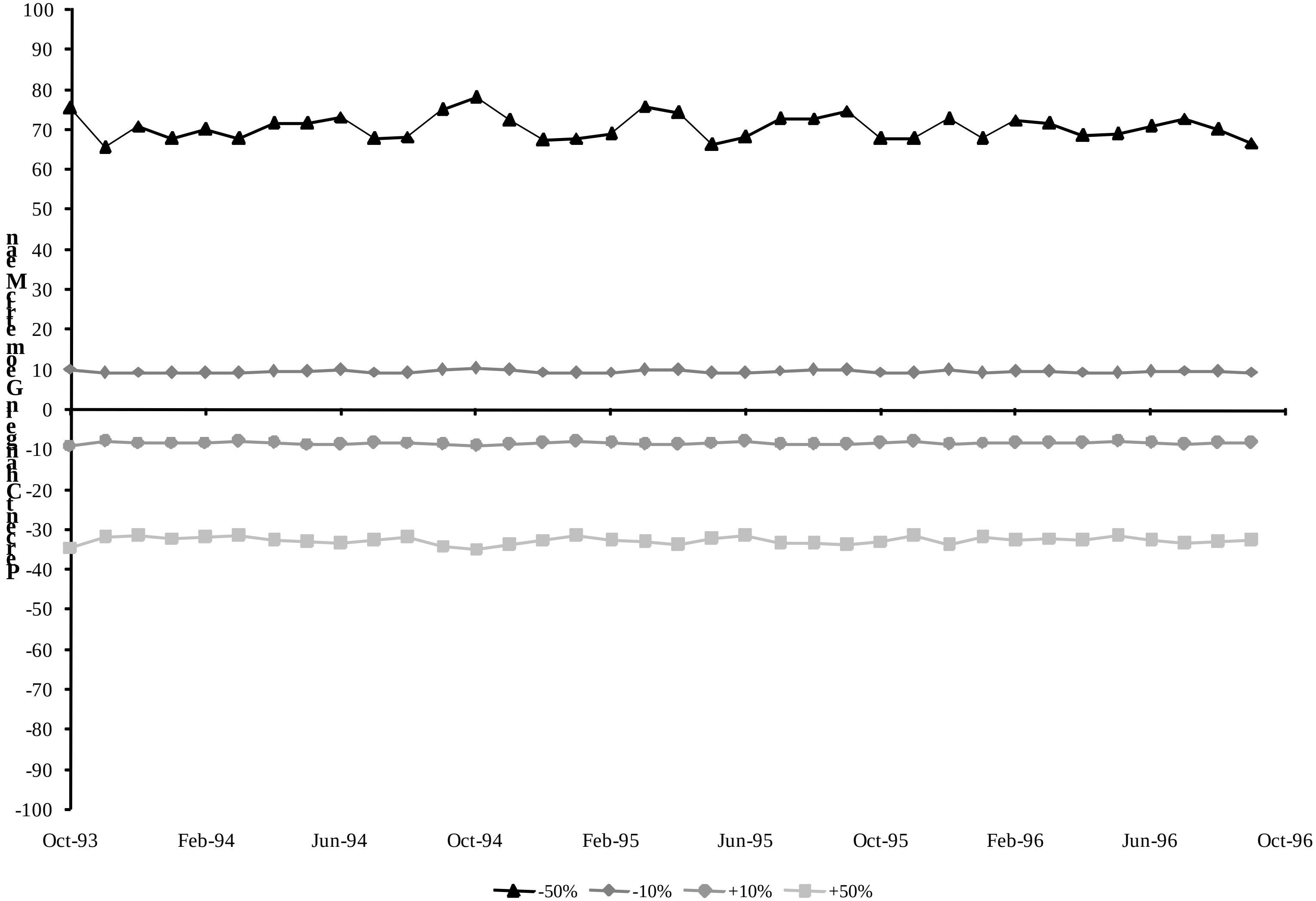

Figure B. 21 Results of sensitivity analysis on monthly mean concentrations as affected by changes in the in-stream first-order decay rate (FSTDEC).

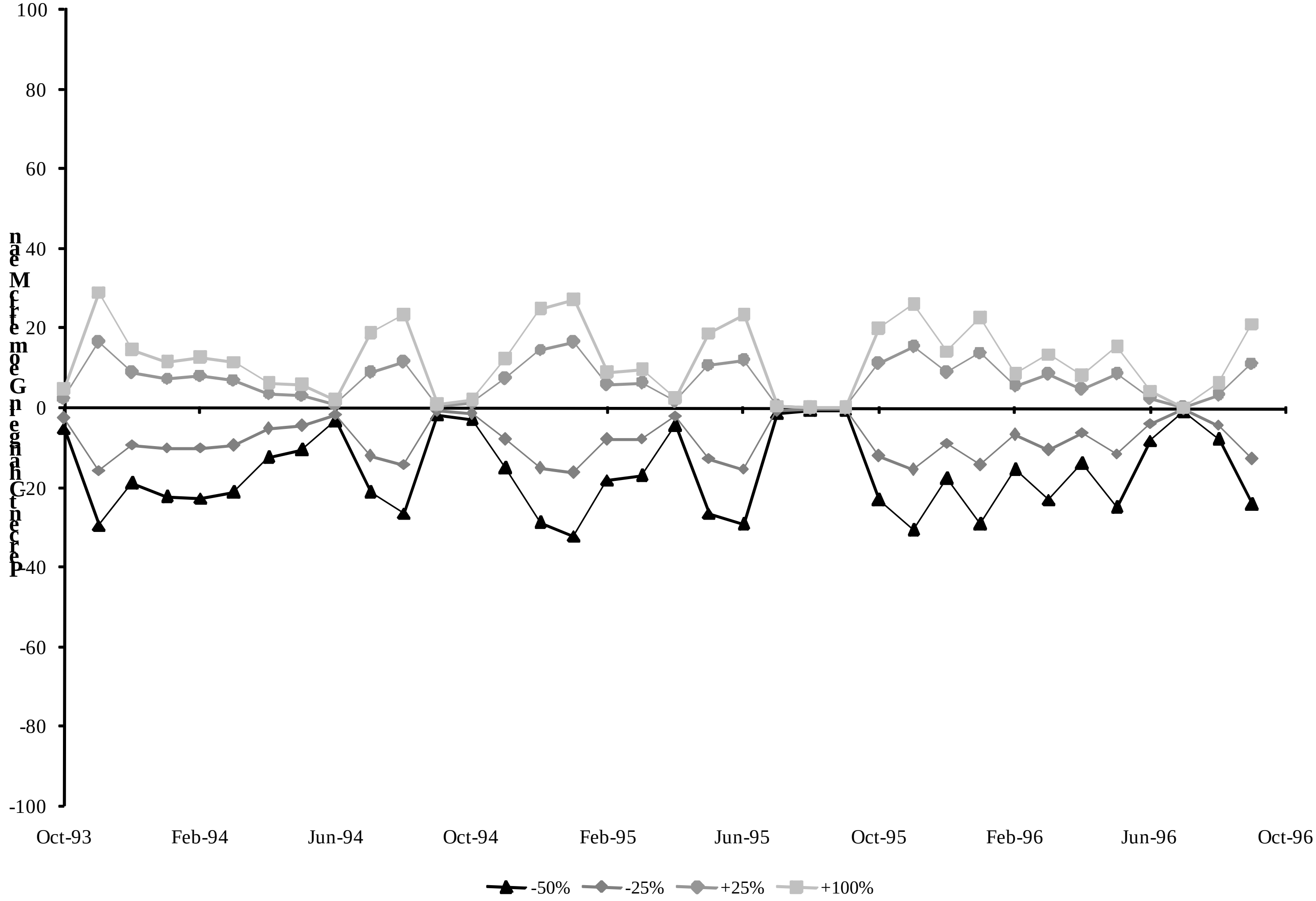

Figure B. 22 Results of sensitivity analysis on monthly mean concentrations as affected by changes in maximum fecal accumulation on land (MON-SQOLIM).

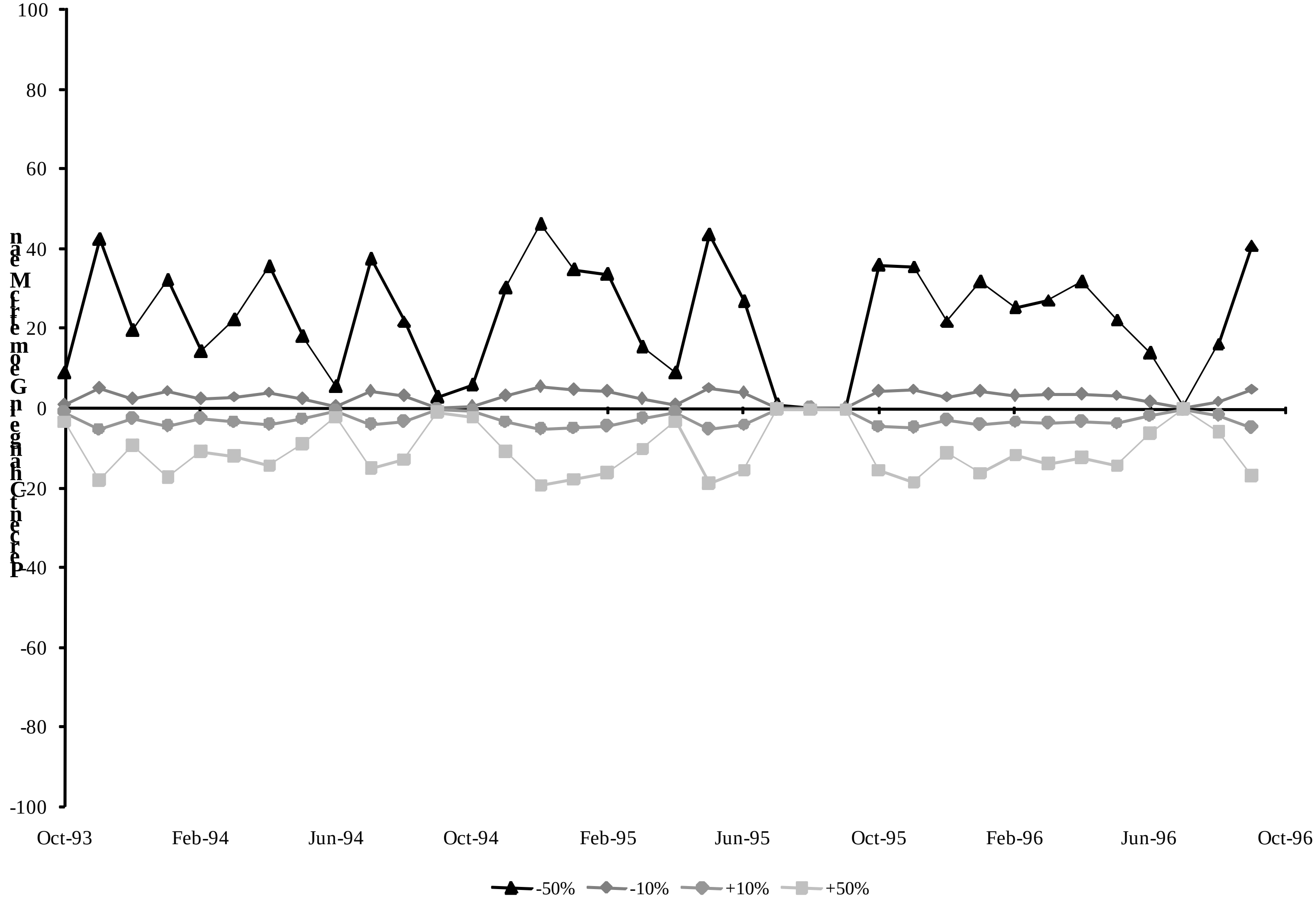

Figure B. 23 Results of sensitivity analysis on monthly mean concentrations as affected by changes in the wash-off rate from land surfaces (WSQOP).

In addition to analyzing the sensitivity of the model response to changes in water quality transport and die-off parameters, the response of the model to changes in land-based and direct loads was also analyzed. It is evident in Figure B.24 that the model predicts a linear relationship between increased fecal coliform concentrations in both land and direct applications, and total load reaching the stream. The magnitude of this relationship differs between land applied and direct loadings; a 100% increase in the land applied loads results in an increase of about 80% in stream loads, while a 100% increase in direct loads results in approximately a 15% increase in stream loads. Both direct loads and land applied loads have a significant impact on the geometric mean concentrations (Figures B.25 and B.26).

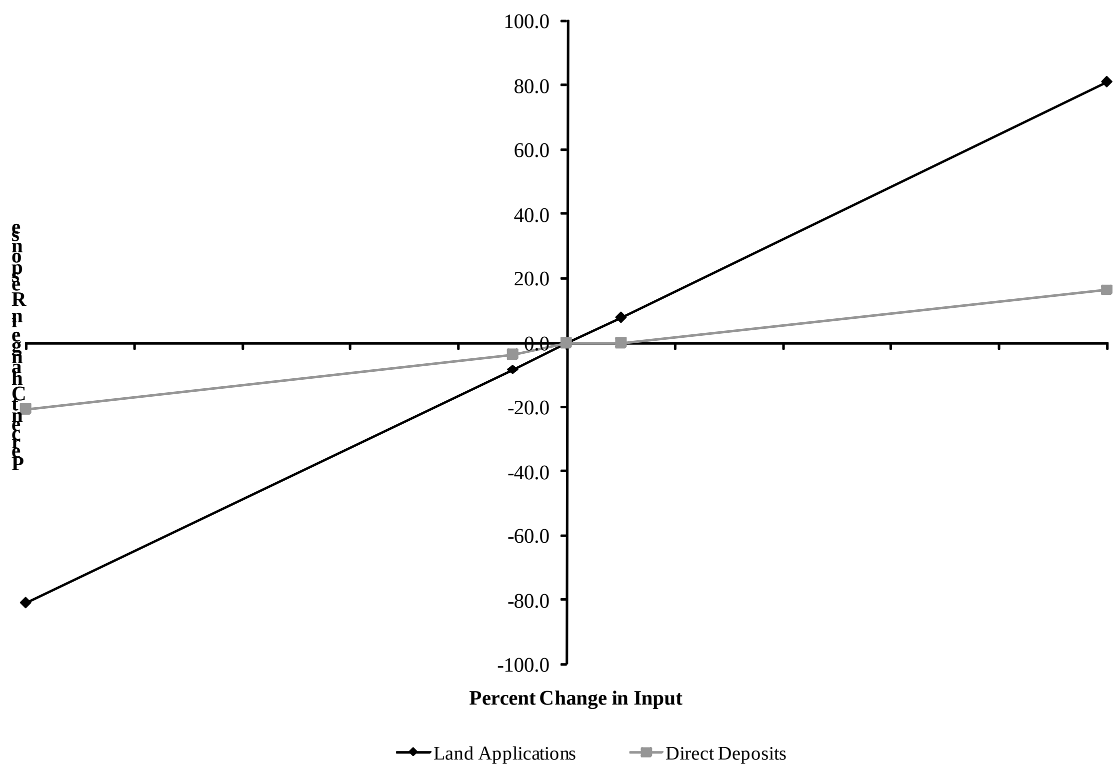

Figure B. 24 Results of total loading sensitivity analysis for outlet of the Little River Watershed study area.

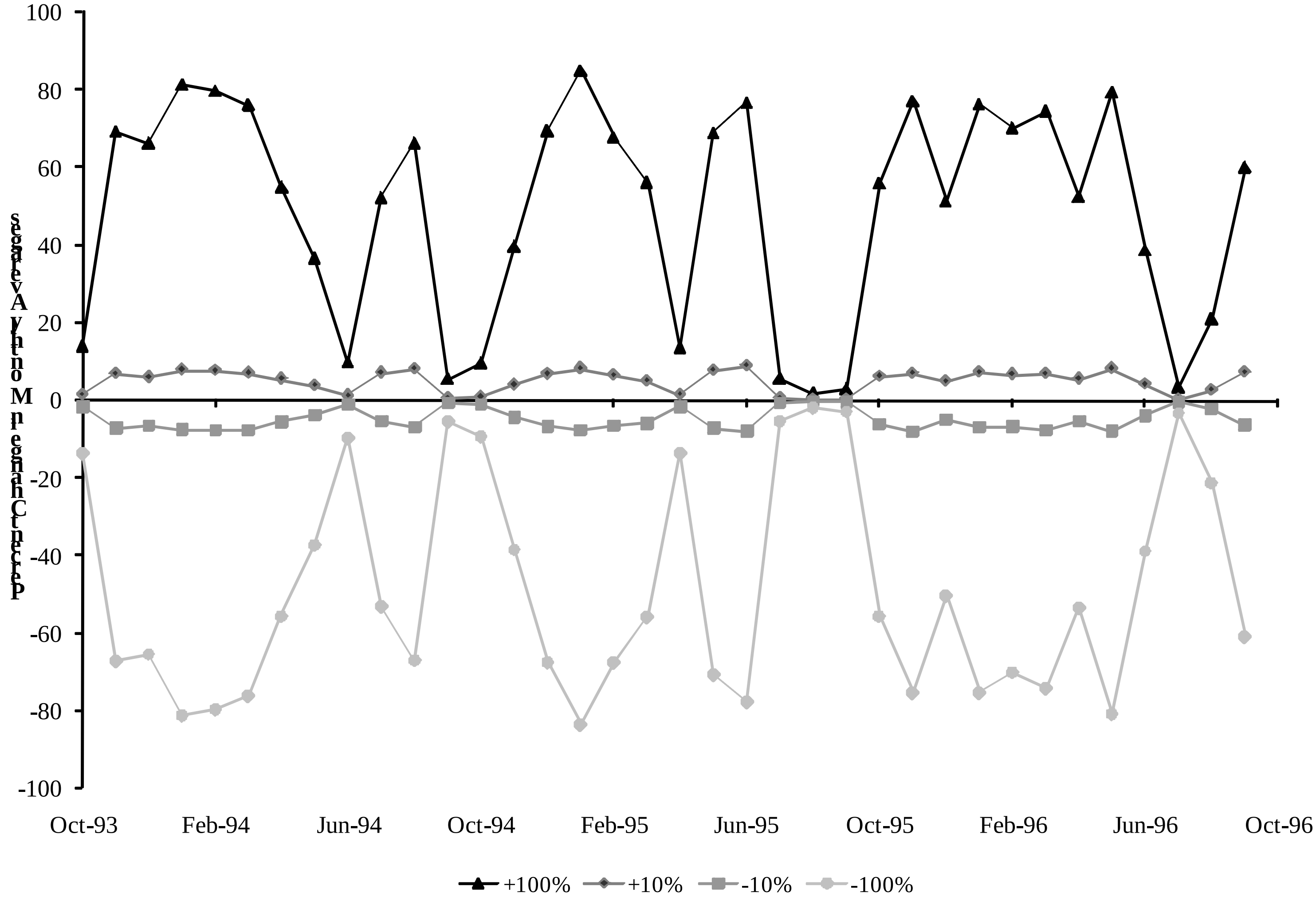

Figure B. 25 Results of sensitivity analysis on monthly geometric-mean concentrations in the Little River Watershed study area, as affected by changes in land-based loadings.

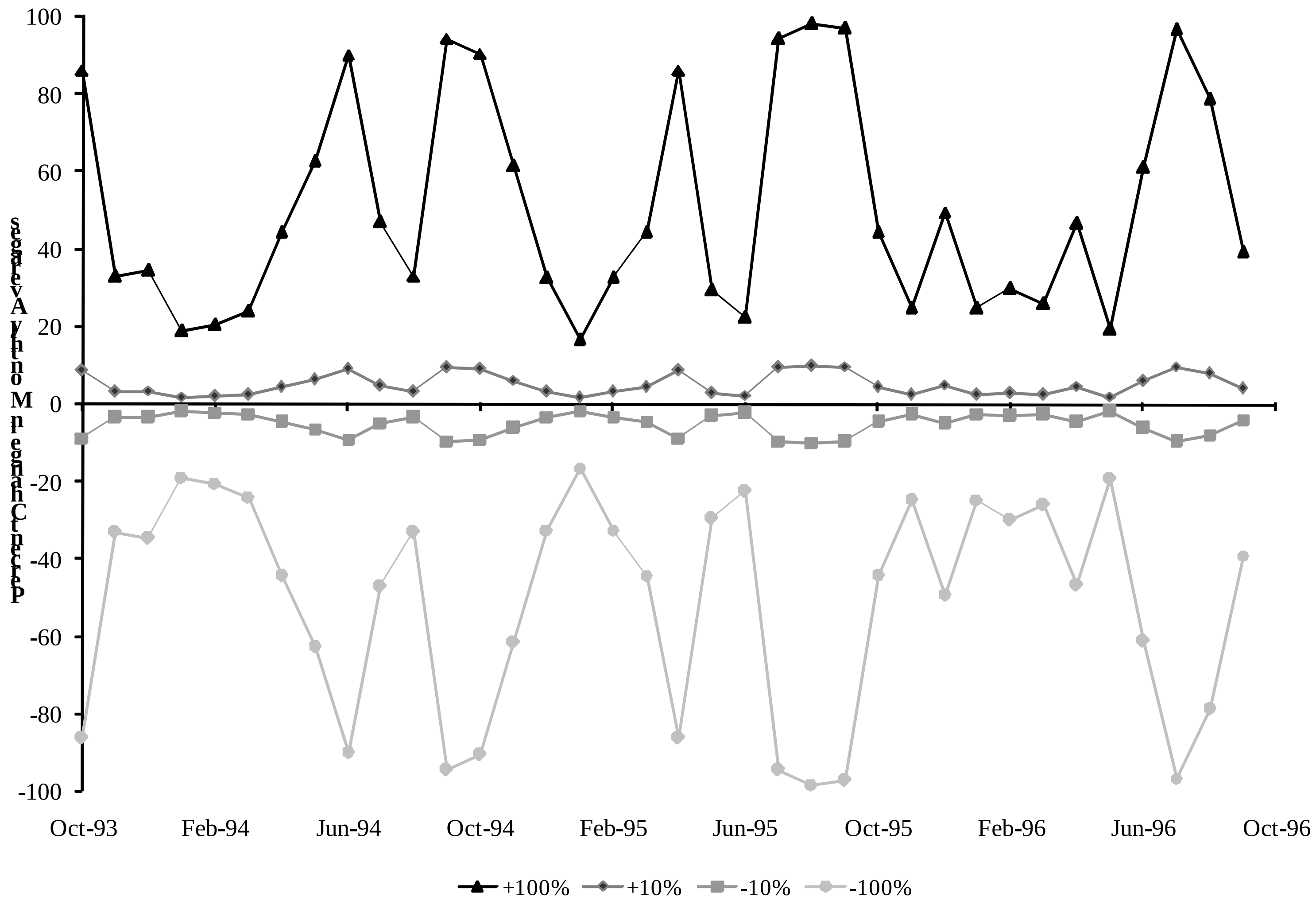

Figure B. 26 Results of sensitivity analysis on monthly geometric-mean concentrations in the Little River Watershed study area, as affected by changes in loadings from direct nonpoint sources.

Model Calibration and Validation Processes

Calibration and validation are performed in order to ensure that the model accurately represents the hydrologic and water quality processes in the watershed. The model's hydrologic parameters were set based on available soils, land use, and topographic data. Through calibration, these parameters were adjusted within appropriate ranges until the model performance was deemed acceptable.

HSPF - Hydrologic Calibration and Validation

The model calibrated for hydrologic accuracy using daily flow data for the period October 1993 through September 1996. The modeled output from subwatershed 3 was compared against the Little River USGS Gaging Station #03170000 data

HSPF parameters that were adjusted during the hydrologic calibration represented: the amount of evapotranspiration from the root zone (LZETP), the recession rates for groundwater (AGWRC) and interflow (IRC), the amount of soil moisture storage in the upper zone (UZSN) and lower zone (LZSN), the amount of interception storage (CEPSC), the infiltration capacity (INFILT), the amount of soil water contributing to interflow (INTFW), deep groundwater inflow fraction (DEEPER), baseflow PET (BASETP), and groundwater recession flow (KVARY). Table B.12 contains the possible range for the above parameters along with the initial estimate and final calibrated value. State variables in the PERLND water (PWAT) section of the User's Control Input (UCI) file were adjusted to reflect initial conditions.

Table B. 12 Initial hydrologic parameters estimated for the Little River TMDL study area, and resulting final values after calibration.

Parameter	Units	Possible Range of Parameter Value	Initial Parameter Estimate	Final Calibrated Parameter Value
LZSN	in	2.0 – 15.0	10	3.8
INFILT	in/hr	0.001 – 0.50	0.0796 – 0.4272	0.0398 – 0.2136
KVARY	1/in	0.0 – 5.0	1	0.15
AGWRC	1/day	0.85 – 0.999	0.995	0.991
DEEPFR	---	0.0 – 0.50	0.10	0.01
BASETP	---	0.0 – 0.20	0 – 0.02	0.0
INTFW	---	1.0 – 10.0	1.0	3.0
IRC	1/day	0.30 – 0.85	0.3	0.85
MON-INTERCEPT	in	0.01 – 0.40	0.01 – 0.20	0.01 – 0.2
MON-UZSN	in	0.05 – 2.0	0.4 – 1.0	0.6 – 1.5
MON-LZETP	---	0.1 – 0.9	0.01 – 0.8	0.01 – 0.4

* Represents a multiplier; + represents an addition

Table B.13 shows the percent difference (or error) between observed and modeled data for total in-stream flows, upper 10% flows, and lower 50% flows during model calibration. These values represent a close agreement with the observed data, indicating the model was well calibrated. Figures B.27 and B.28 graphically show these comparisons.

Table B. 13 Hydrology calibration model performance from 10/1/1993 through 9/30/1996 at USGS Gaging Station #03170000 on the Little River Watershed (subwatershed 3).

Criterion	Observed	Modeled	Error
Total In-stream Flow:	51.49	49.66	-3.56%
Upper 10% Flow Values:	16.46	16.89	2.56%
Lower 50% Flow Values:	13.33	12.39	-7.04%
Winter Flow Volume	19.84	21.23	6.98%
Spring Flow Volume	14.10	11.94	-15.33%
Summer Flow Volume	9.51	8.47	-10.89%
Fall Flow Volume	8.04	8.02	-0.26%
Total Storm Volume	33.61	36.39	8.25%
Winter Storm Volume	15.44	17.94	16.22%
Spring Storm Volume	9.63	8.63	-10.43%
Summer Storm Volume	5.02	5.12	2.12%
Fall Storm Volume	3.52	4.69	33.12%

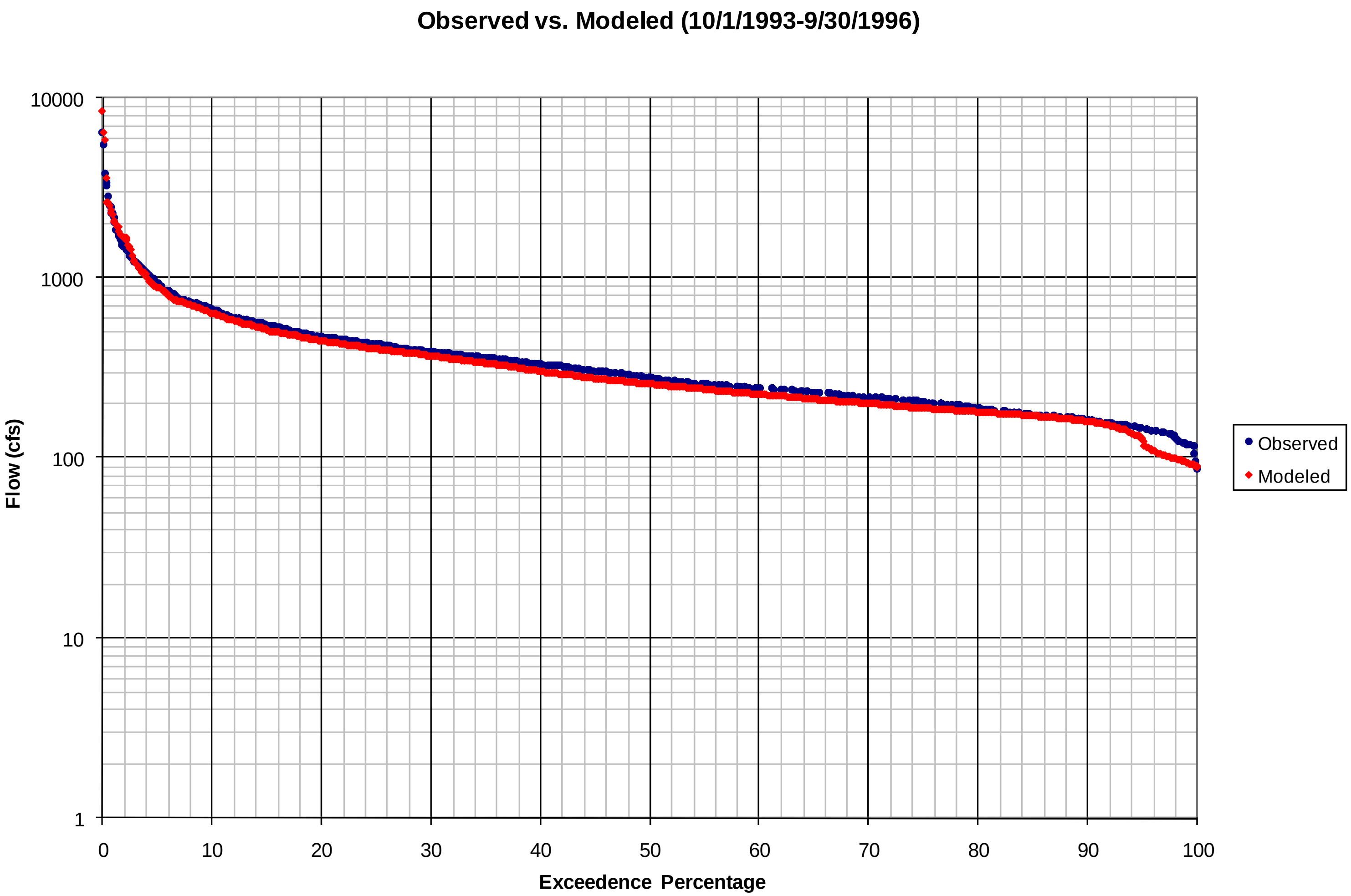

Figure B. 27 Little River modeled flow duration versus USGS Gaging Station #03170000 data from 10/1/1993 to 9/30/1996 (subwatershed 3).

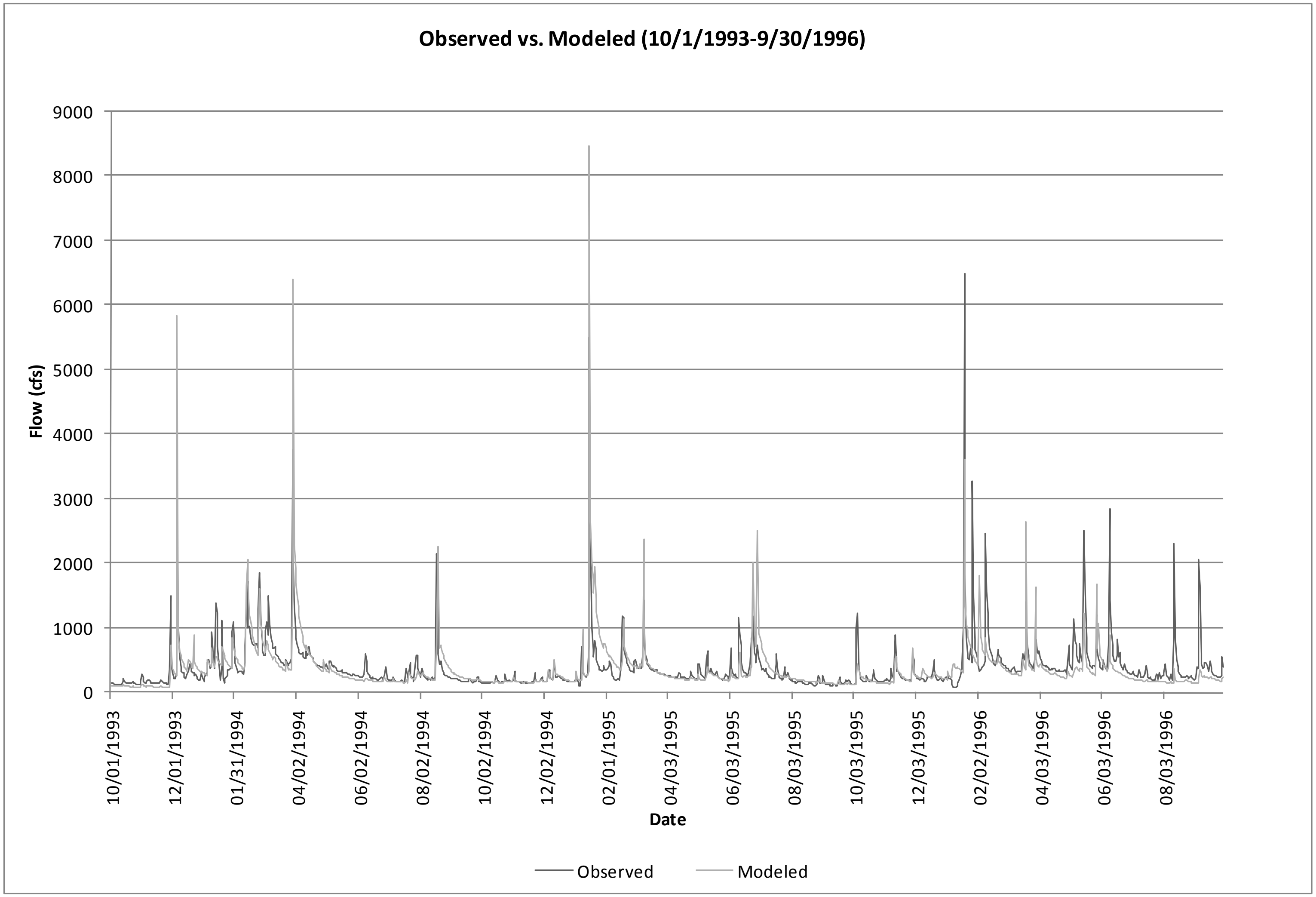

Figure B. 28 Little River modeled results versus USGS Gaging Station #03170000 data from 10/1/1993 to 9/30/1996 (subwatershed 3).

The modeled output was validated for the period of 10/2005 to 9/2008. Simulated flow at subwatershed 3 was compared with daily observed flow at the Little River USGS Gaging Station #03170000. Table B.14 shows the percent difference (or error) between observed and modeled data for total in-stream flows, upper 10% flows, and lower 50% flows during model calibration. These values represent a close agreement with the observed data, indicating the model was well calibrated and has been validated during a different time period. Figures B.29 and B.30 graphically show these comparisons.

Table B. 14 Hydrology validation model performance from 10/1/2005 through 9/30/2008 at USGS Gaging Station #03170000 on the Little River (subwatershed 3).

Criterion	Observed	Modeled	Error
Total In-stream Flow:	70.74	67.47	-4.62%
Upper 10% Flow Values:	21.54	19.55	-9.26%
Lower 50% Flow Values:	17.93	18.29	2.01%
Winter Flow Volume	21.72	20.26	-6.74%
Spring Flow Volume	20.20	17.38	-13.94%
Summer Flow Volume	10.08	11.30	12.04%
Fall Flow Volume	18.74	18.53	-1.08%
Total Storm Volume	55.94	45.01	-19.53%
Winter Storm Volume	18.05	14.70	-18.56%
Spring Storm Volume	16.49	11.78	-28.58%
Summer Storm Volume	6.40	5.65	-11.74%
Fall Storm Volume	14.99	12.88	-14.08%

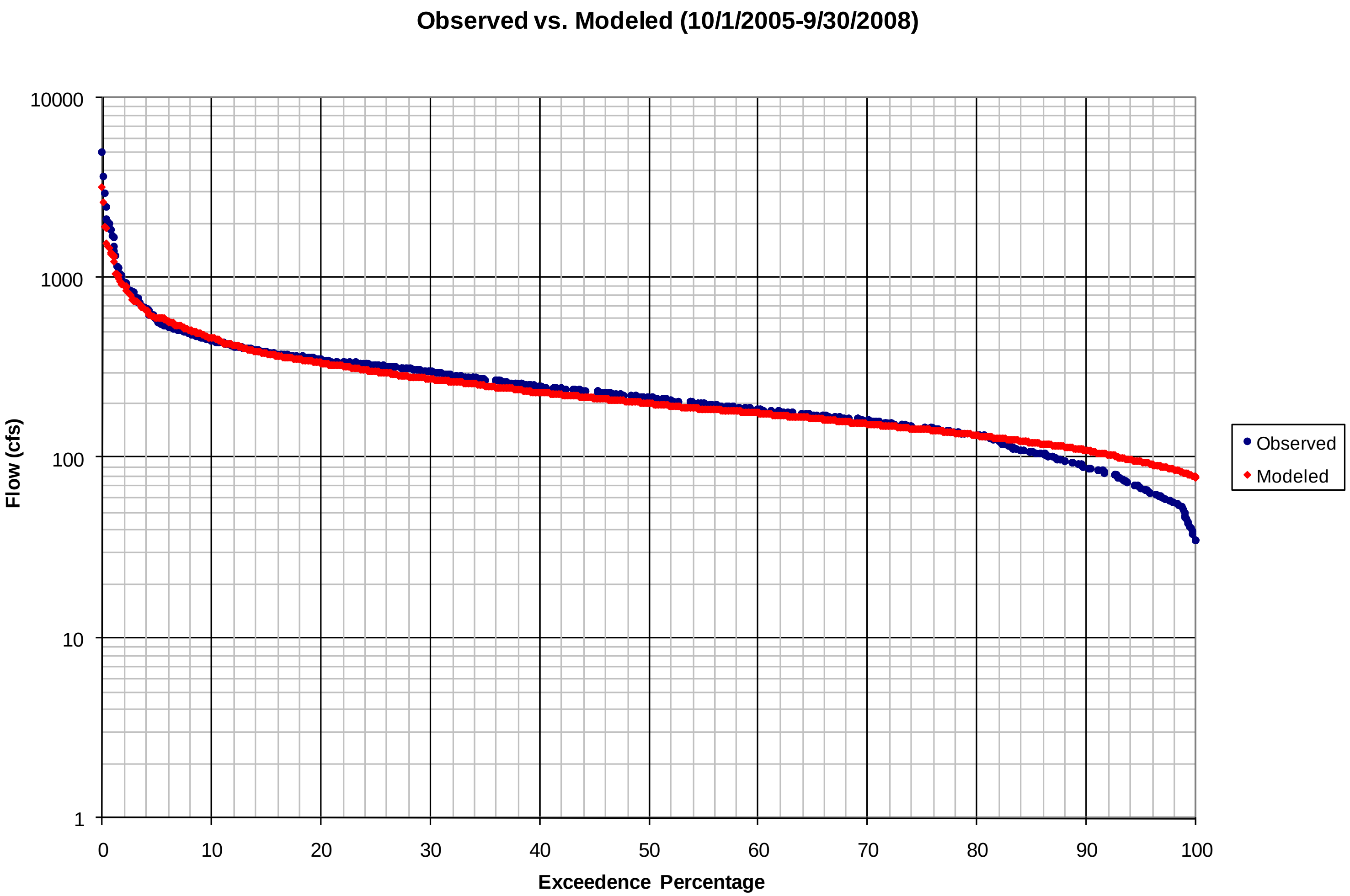

Figure B. 29 Little River modeled flow duration versus USGS Gaging Station #03170000 data for validation (subwatershed 3).

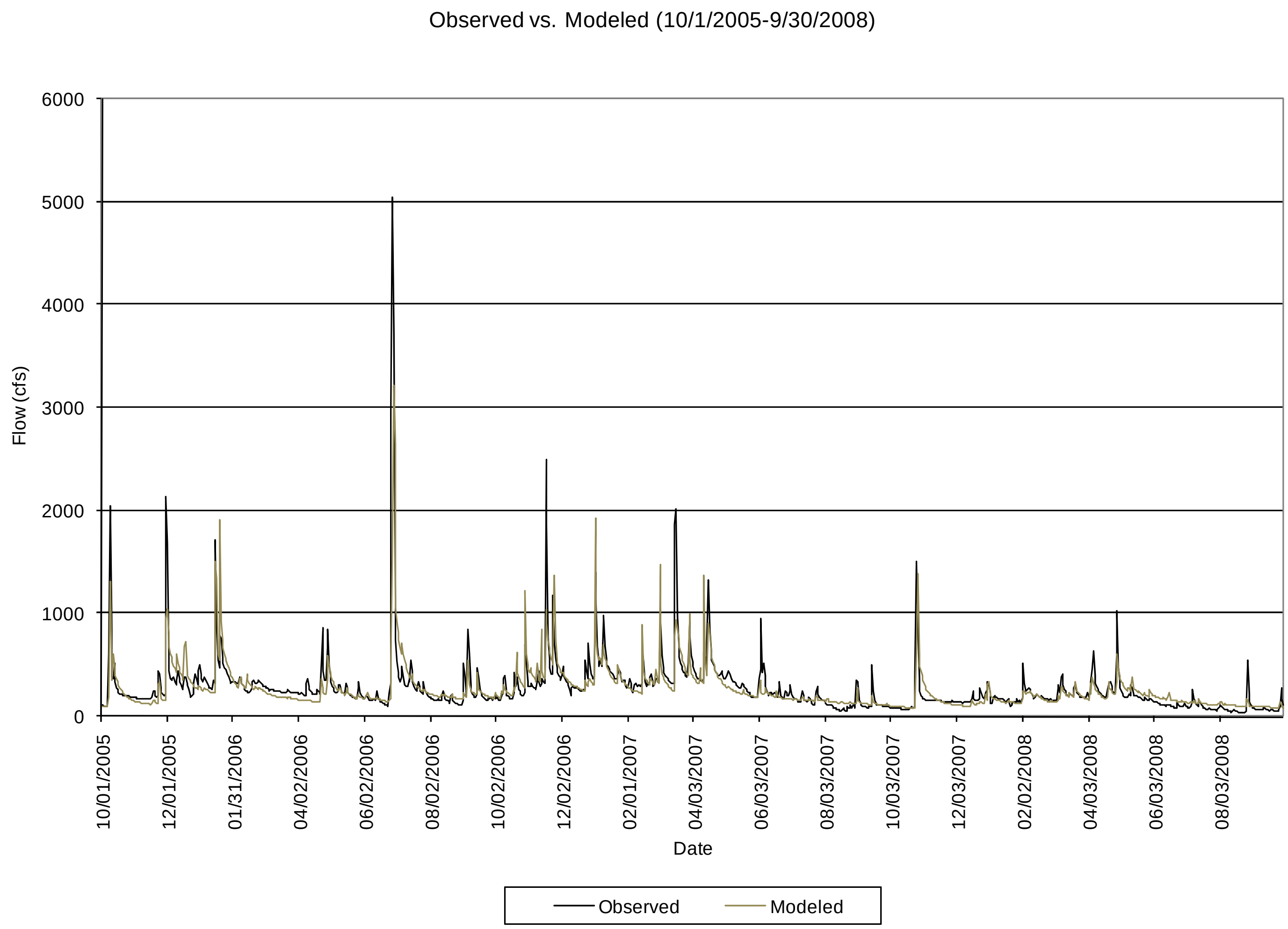

Figure B. 30 Little River validation modeled results versus USGS Gaging Station #03170000 data from (subwatershed 3).

HSPF – Bacteria Water Quality Calibration

Water quality calibration is complicated by a number of factors; first, water quality (*E. coli*) concentrations are highly dependent on flow conditions. Any variability associated with the modeling of stream flow compounds the variability in modeling water quality parameters. Second, the concentration of *E. coli* is particularly variable. Variability in location and timing of fecal deposition, variability in the density of bacteria in feces (among species and for an individual animal), environmental impacts on re-growth and die-off, and variability in delivery to the stream all lead to difficulty in measuring and modeling *E. coli* concentrations. Additionally, the VADEQ data were censored at specific high and low values (e.g. 8,000 cfu/100ml or 16,000 cfu/100ml as highs or 100 cfu/100 mL as low value). Limited amount of measured data for use in calibration and the practice of censoring both high and low concentrations impede the calibration process.

Four parameters were utilized for model adjustment: in-stream first-order decay rate (FSTDEC), monthly maximum accumulation on land (MON-SQOLIM), the rate of surface runoff that will remove 90% of stored fecal bacteria per hour (WSQOP), and the temperature correction coefficient for first-order decay of quality (THFST). All of these parameters were initially set at expected levels for the watershed conditions and adjusted within reasonable limits until an acceptable match between measured and modeled bacteria concentrations was established. Depending on the type of available bacteria data, either fecal coliform and *E. coli* monitored data were used. Table B.15 shows the model parameters utilized in calibration with their typical ranges, initial estimates, and final calibrated values. Bacteria calibration was conducted for the period of October 2000 to September 2003.

Table B. 15 Model parameters utilized for water quality calibration.

Parameter	Units	Typical Range	Initial Parameter Estimate	Calibrated Parameter Value
MON-SQOLIM	FC/ac	1.0E-02 – 1.0E+30	0.0 – 3.6E+11	0.0 – 1.0E+13
WSQOP	in/hr	0.05 – 3.00	0.0 – 2.80	0.4 – 1.80
FSTDEC	1/day	0.01 – 10.00	1.0	9.0
THFST	none	1.0 – 2.0	1.07	1.07

Figure B.31 shows the results of water quality calibration. Monitored values are an instantaneous snapshot of the bacteria level, whereas the modeled values are daily averages based on hourly modeling. The hourly bacteria concentrations as predicted by the model have a rage wider than the average daily and encompass the high and low observed data points. The modeled data follows the trend of monitored data.

Careful inspection of graphical comparisons between continuous simulation results and limited observed points was the primary tool used to guide the calibration process. Table B.16 shows the predicted and observed values for the maximum value, geometric mean, and single sample (SS) instantaneous violations for the Little River.

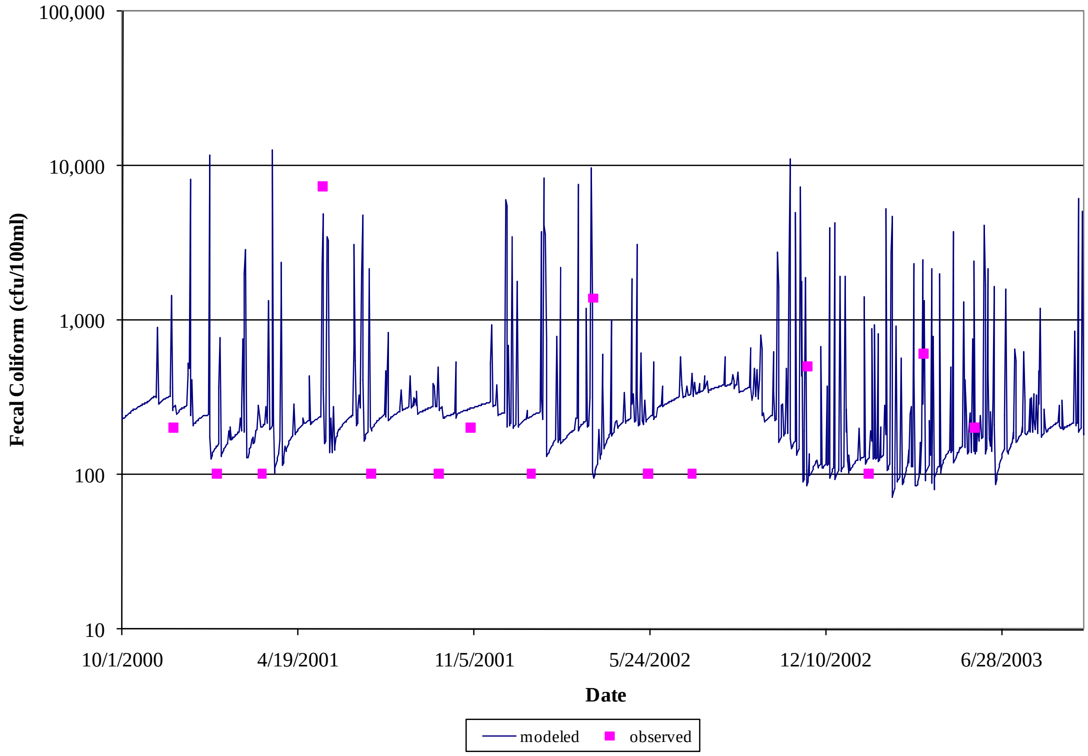

Figure B. 31 Fecal coliform calibration for 10/1/2000 to 9/30/2003 for VADEQ station 9-LRV000.34 in subwatershed 1 on the Little River.

Table B. 16 Monitored and simulated maximum value, geometric mean, and single sample violation percentage for the calibration period.

Station	Subwatershed	Maximum Value (cfu/100ml)		Geometric Mean (cfu/100ml)		SS % violations [1]	
		Monitored	Simulated	Monitored	Simulated	Monitored	Simulated
9-LRV000.34	1	7,300	12,730	200	255	25%	12%

[1] SS = single sample instantaneous standard violations (>400 cfu/100mL)

HSPF – Bacteria Water Quality Validation

Bacteria water quality model validation was performed on the same station used in calibration (9-LRV000.34) for the period of October 1997 to September 2000. Figure B.32 shows the results of water quality validation. Table B.17 shows the predicted and observed values for the maximum value, geometric mean, and single sample (SS) instantaneous violations for the Little River.

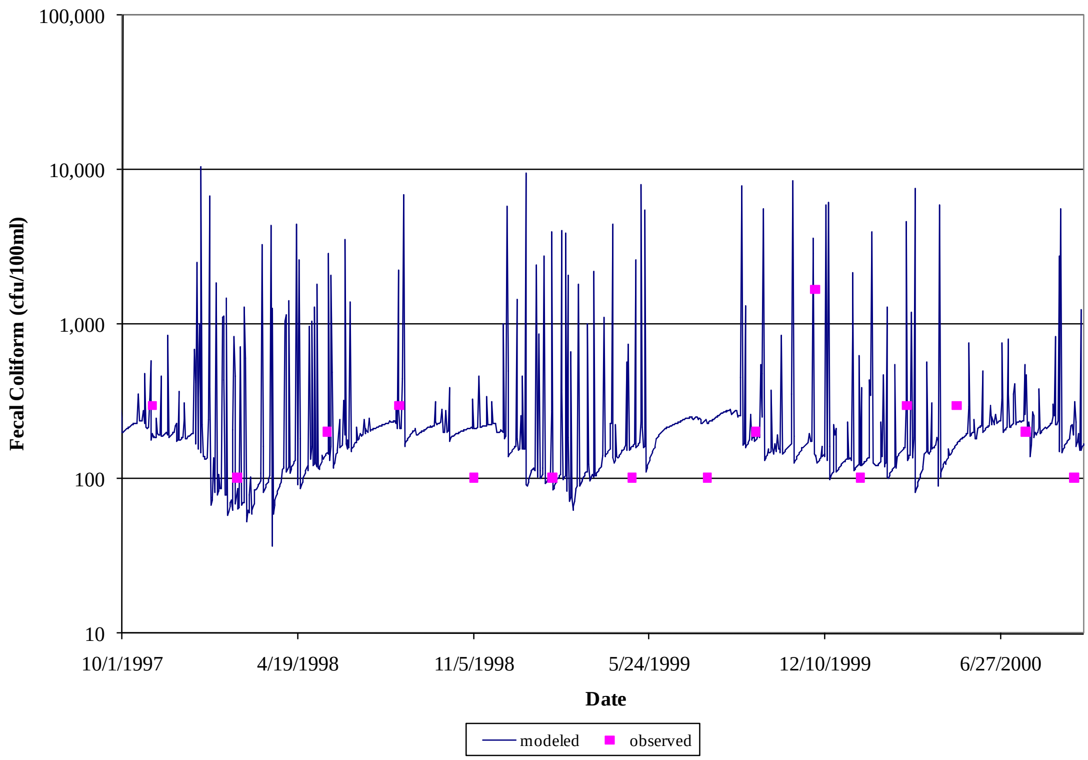

Figure B. 32 Fecal coliform validation for 10/1/1997 to 9/30/2000 for VADEQ station 9-LRV000.34 in subwatershed 1 on the Little River.

Table B. 17 Monitored and simulated maximum value, geometric mean, and single sample violation percentage for the validation period.

Station	Subwatershed	Maximum Value (cfu/100ml)		Geometric Mean (cfu/100ml)		SS % violations[1]	
		Monitored	Simulated	Monitored	Simulated	Monitored	Simulated
9-LRV000.34	1	1,700	10,501	186	203	7%	9%

[1] SS = single sample instantaneous standard violations (>400 cfu/100m)

APPENDIX C

Current conditions fecal coliform loads

Table C. 1 Current conditions of land applied fecal coliform load for the Little River by land-use(Sub-watersheds 1,2,3,4,5,6,7,8,9,10,11,12,13,14,16,17,18,19,20,21,25,26,27):

Land-use	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual Total Load (cfu/yr)
Barren	47.2E10	42.6E10	47.2E10	45.6E10	47.2E10	45.6E10	47.2E10	47.2E10	45.6E10	47.2E10	45.6E10	47.2E10	55.5E11
Comm.	49.9E10	45.1E10	49.9E10	48.3E10	49.9E10	48.3E10	49.9E10	49.9E10	48.3E10	49.9E10	48.3E10	49.9E10	58.7E11
Crop	33.6E12	38.0E12	33.5E13	33.5E13	33.5E13	43.1E11	44.5E11	44.5E11	10.1E13	33.5E13	33.5E13	33.6E12	18.9E14
Developed	94.9E12	84.8E12	92.0E12	88.2E12	90.1E12	86.3E12	87.3E12	87.3E12	84.5E12	86.4E12	84.5E12	91.1E12	10.6E14
Forest	47.6E13	43.0E13	47.6E13	46.1E13	47.6E13	46.1E13	47.6E13	47.6E13	46.1E13	47.6E13	46.1E13	47.6E13	56.0E14
Livestock Access	96.9E12	87.5E12	11.7E13	14.0E13	14.4E13	15.9E13	16.5E13	16.5E13	14.0E13	11.7E13	11.3E13	11.0E13	15.6E14
Pasture	25.8E14	23.3E14	25.5E14	24.3E14	25.1E14	24.4E14	25.2E14	25.2E14	24.3E14	25.5E14	24.7E14	25.8E14	29.9E15
Wetland	50.4E11	45.5E11	50.4E11	48.8E11	50.4E11	48.8E11	50.4E11	50.4E11	48.8E11	50.4E11	48.8E11	50.4E11	59.4E12

Table C. 2 **Monthly, directly deposited fecal coliform loads in each reach of the Little River (Reaches 1,2,3,4,5,6,7,8,9,10,11,12,13,14,16,17,18,19,20,21,25,26,27):**

Source Type	Reach ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total Load (cfu/yr)
Human/Pet	1	51.5E10	46.5E10	51.5E10	49.9E10	51.5E10	49.9E10	51.5E10	51.5E10	49.9E10	51.5E10	49.9E10	51.5E10	60.7E11
Livestock	1	10.2E11	92.0E10	14.6E11	19.7E11	20.4E11	23.9E11	24.7E11	24.7E11	19.7E11	14.6E11	14.1E11	10.2E11	20.6E12
Wildlife	1	32.1E10	29.0E10	32.1E10	31.1E10	32.1E10	31.1E10	32.1E10	32.1E10	31.1E10	32.1E10	31.1E10	32.1E10	37.8E11
Human/Pet	2	23.2E11	21.0E11	23.2E11	22.5E11	23.2E11	22.5E11	23.2E11	23.2E11	22.5E11	23.2E11	22.5E11	23.2E11	27.3E12
Livestock	2	31.5E11	28.5E11	45.0E11	61.0E11	63.1E11	74.1E11	76.6E11	76.6E11	61.0E11	45.0E11	43.6E11	31.5E11	63.8E12
Wildlife	2	61.8E10	55.8E10	61.8E10	59.8E10	61.8E10	59.8E10	61.8E10	61.8E10	59.8E10	61.8E10	59.8E10	61.8E10	72.7E11
Human/Pet	3	53.7E11	48.5E11	53.7E11	52.0E11	53.7E11	52.0E11	53.7E11	53.7E11	52.0E11	53.7E11	52.0E11	53.7E11	63.3E12
Livestock	3	19.0E11	17.2E11	27.2E11	36.8E11	38.1E11	44.7E11	46.2E11	46.2E11	36.8E11	27.2E11	26.3E11	19.0E11	38.5E12
Wildlife	3	15.7E11	14.2E11	15.7E11	15.2E11	15.7E11	15.2E11	15.7E11	15.7E11	15.2E11	15.7E11	15.2E11	15.7E11	18.5E12
Human/Pet	4	25.6E11	23.1E11	25.6E11	24.8E11	25.6E11	24.8E11	25.6E11	25.6E11	24.8E11	25.6E11	24.8E11	25.6E11	30.1E12
Livestock	4	52.7E10	47.6E10	75.3E10	10.2E11	10.5E11	12.4E11	12.8E11	12.8E11	10.2E11	75.3E10	72.9E10	52.7E10	10.7E12
Wildlife	4	10.4E11	94.1E10	10.4E11	10.1E11	10.4E11	10.1E11	10.4E11	10.4E11	10.1E11	10.4E11	10.1E11	10.4E11	12.3E12
Human/Pet	5	22.9E11	20.7E11	22.9E11	22.2E11	22.9E11	22.2E11	22.9E11	22.9E11	22.2E11	22.9E11	22.2E11	22.9E11	27.0E12
Livestock	5	48.4E10	43.7E10	69.1E10	93.6E10	96.8E10	11.4E11	11.7E11	11.7E11	93.6E10	69.1E10	66.9E10	48.4E10	97.8E11
Wildlife	5	76.6E10	69.2E10	76.6E10	74.2E10	76.6E10	74.2E10	76.6E10	76.6E10	74.2E10	76.6E10	74.2E10	76.6E10	90.2E11
Human/Pet	6	62.9E10	56.8E10	62.9E10	60.8E10	62.9E10	60.8E10	62.9E10	62.9E10	60.8E10	62.9E10	60.8E10	62.9E10	74.0E11
Livestock	6	12.3E10	11.1E10	17.6E10	23.8E10	24.6E10	28.9E10	29.9E10	29.9E10	23.8E10	17.6E10	17.0E10	12.3E10	24.9E11
Wildlife	6	28.3E10	25.6E10	28.3E10	27.4E10	28.3E10	27.4E10	28.3E10	28.3E10	27.4E10	28.3E10	27.4E10	28.3E10	33.3E11
Human/Pet	7	29.7E11	26.8E11	29.7E11	28.7E11	29.7E11	28.7E11	29.7E11	29.7E11	28.7E11	29.7E11	28.7E11	29.7E11	34.9E12
Livestock	7	59.6E10	53.9E10	85.2E10	11.5E11	11.9E11	14.0E11	14.5E11	14.5E11	11.5E11	85.2E10	82.4E10	59.6E10	12.1E12
Wildlife	7	75.8E10	68.5E10	75.8E10	73.4E10	75.8E10	73.4E10	75.8E10	75.8E10	73.4E10	75.8E10	73.4E10	75.8E10	89.3E11

Table C. 3 Monthly, directly deposited fecal coliform loads in each reach of the Little River (Reaches 1,2,3,4,5,6,7,8,9,10,11,12,13,14,16,17,18,19,20,21,25,26, (cont.)

Source Type	Reach ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total Load (cfu/yr)
Human/Pet	8	57.2E10	51.6E10	57.2E10	55.3E10	57.2E10	55.3E10	57.2E10	57.2E10	55.3E10	57.2E10	55.3E10	57.2E10	67.3E11
Livestock	8	22.8E10	20.6E10	32.5E10	44.1E10	45.5E10	53.5E10	55.3E10	55.3E10	44.1E10	32.5E10	31.5E10	22.8E10	46.0E11
Wildlife	8	39.0E10	35.2E10	39.0E10	37.7E10	39.0E10	37.7E10	39.0E10	39.0E10	37.7E10	39.0E10	37.7E10	39.0E10	45.9E11
Human/Pet	9	38.6E10	34.8E10	38.6E10	37.3E10	38.6E10	37.3E10	38.6E10	38.6E10	37.3E10	38.6E10	37.3E10	38.6E10	45.4E11
Livestock	9	60.9E10	55.0E10	87.0E10	11.8E11	12.2E11	14.3E11	14.8E11	14.8E11	11.8E11	87.0E10	84.2E10	60.9E10	12.3E12
Wildlife	9	68.6E10	61.9E10	68.6E10	66.4E10	68.6E10	66.4E10	68.6E10	68.6E10	66.4E10	68.6E10	66.4E10	68.6E10	80.7E11
Human/Pet	10	16.6E11	15.0E11	16.6E11	16.1E11	16.6E11	16.1E11	16.6E11	16.6E11	16.1E11	16.6E11	16.1E11	16.6E11	19.6E12
Livestock	10	81.1E10	73.3E10	11.6E11	15.7E11	16.2E11	19.1E11	19.7E11	19.7E11	15.7E11	11.6E11	11.2E11	81.1E10	16.4E12
Wildlife	10	89.7E10	81.0E10	89.7E10	86.8E10	89.7E10	86.8E10	89.7E10	89.7E10	86.8E10	89.7E10	86.8E10	89.7E10	10.6E12
Human/Pet	11	48.0E11	43.4E11	48.0E11	46.5E11	48.0E11	46.5E11	48.0E11	48.0E11	46.5E11	48.0E11	46.5E11	48.0E11	56.6E12
Livestock	11	12.6E11	11.3E11	17.9E11	24.3E11	25.1E11	29.5E11	30.5E11	30.5E11	24.3E11	17.9E11	17.4E11	12.6E11	25.4E12
Wildlife	11	12.4E11	11.2E11	12.4E11	12.0E11	12.4E11	12.0E11	12.4E11	12.4E11	12.0E11	12.4E11	12.0E11	12.4E11	14.6E12
Human/Pet	12	42.0E11	37.9E11	42.0E11	40.6E11	42.0E11	40.6E11	42.0E11	42.0E11	40.6E11	42.0E11	40.6E11	42.0E11	49.4E12
Livestock	12	14.6E11	13.2E11	20.9E11	28.3E11	29.2E11	34.4E11	35.5E11	35.5E11	28.3E11	20.9E11	20.2E11	14.6E11	29.6E12
Wildlife	12	13.3E11	12.0E11	13.3E11	12.8E11	13.3E11	12.8E11	13.3E11	13.3E11	12.8E11	13.3E11	12.8E11	13.3E11	15.6E12
Human/Pet	13	30.3E11	27.3E11	30.3E11	29.3E11	30.3E11	29.3E11	30.3E11	30.3E11	29.3E11	30.3E11	29.3E11	30.3E11	35.6E12
Livestock	13	89.4E10	80.7E10	12.8E11	17.3E11	17.9E11	21.0E11	21.7E11	21.7E11	17.3E11	12.8E11	12.4E11	89.4E10	18.1E12
Wildlife	13	55.4E10	50.1E10	55.4E10	53.6E10	55.4E10	53.6E10	55.4E10	55.4E10	53.6E10	55.4E10	53.6E10	55.4E10	65.3E11

Table C. 4 Monthly, directly deposited fecal coliform loads in each reach of the Little River (Reaches 1,2,3,4,5,6,7,8,9,10,11,12,13,14,16,17,18,19,20,21,25,26, (cont.)

Source Type	Reach ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total Load (cfu/yr)
Human/Pet	14	27.8E11	25.1E11	27.8E11	26.9E11	27.8E11	26.9E11	27.8E11	27.8E11	26.9E11	27.8E11	26.9E11	27.8E11	32.8E12
Livestock	14	10.3E11	93.2E10	14.7E11	20.0E11	20.6E11	24.3E11	25.1E11	25.1E11	20.0E11	14.7E11	14.3E11	10.3E11	20.9E12
Wildlife	14	35.0E10	31.6E10	35.0E10	33.9E10	35.0E10	33.9E10	35.0E10	35.0E10	33.9E10	35.0E10	33.9E10	35.0E10	41.2E11
Human/Pet	16	11.2E12	10.1E12	11.2E12	10.8E12	11.2E12	10.8E12	11.2E12	11.2E12	10.8E12	11.2E12	10.8E12	11.2E12	13.1E13
Livestock	16	78.8E10	71.2E10	11.3E11	15.3E11	15.8E11	18.5E11	19.1E11	19.1E11	15.3E11	11.3E11	10.9E11	78.8E10	15.9E12
Wildlife	16	13.6E11	12.3E11	13.6E11	13.2E11	13.6E11	13.2E11	13.6E11	13.6E11	13.2E11	13.6E11	13.2E11	13.6E11	16.0E12
Human/Pet	17	41.4E11	37.4E11	41.4E11	40.1E11	41.4E11	40.1E11	41.4E11	41.4E11	40.1E11	41.4E11	40.1E11	41.4E11	48.8E12
Livestock	17	50.9E10	46.0E10	72.8E10	98.6E10	10.2E11	12.0E11	12.4E11	12.4E11	98.6E10	72.8E10	70.4E10	50.9E10	10.3E12
Wildlife	17	58.4E10	52.8E10	58.4E10	56.6E10	58.4E10	56.6E10	58.4E10	58.4E10	56.6E10	58.4E10	56.6E10	58.4E10	68.8E11
Human/Pet	18	45.6E11	41.2E11	45.6E11	44.1E11	45.6E11	44.1E11	45.6E11	45.6E11	44.1E11	45.6E11	44.1E11	45.6E11	53.7E12
Livestock	18	14.3E11	12.9E11	20.4E11	27.7E11	28.6E11	33.6E11	34.7E11	34.7E11	27.7E11	20.4E11	19.8E11	14.3E11	28.9E12
Wildlife	18	10.0E11	90.4E10	10.0E11	96.8E10	10.0E11	96.8E10	10.0E11	10.0E11	96.8E10	10.0E11	96.8E10	10.0E11	11.8E12
Human/Pet	19	87.6E10	79.1E10	87.6E10	84.7E10	87.6E10	84.7E10	87.6E10	87.6E10	84.7E10	87.6E10	84.7E10	87.6E10	10.3E12
Livestock	19	31.8E10	28.7E10	45.4E10	61.5E10	63.5E10	74.6E10	77.1E10	77.1E10	61.5E10	45.4E10	43.9E10	31.8E10	64.2E11
Wildlife	19	25.3E10	22.8E10	25.3E10	24.4E10	25.3E10	24.4E10	25.3E10	25.3E10	24.4E10	25.3E10	24.4E10	25.3E10	29.7E11
Human/Pet	20	22.4E10	20.2E10	22.4E10	21.7E10	22.4E10	21.7E10	22.4E10	22.4E10	21.7E10	22.4E10	21.7E10	22.4E10	26.4E11
Livestock	20	15.0E10	13.6E10	21.5E10	29.1E10	30.1E10	35.3E10	36.5E10	36.5E10	29.1E10	21.5E10	20.8E10	15.0E10	30.4E11
Wildlife	20	26.4E10	23.9E10	26.4E10	25.6E10	26.4E10	25.6E10	26.4E10	26.4E10	25.6E10	26.4E10	25.6E10	26.4E10	31.1E11

Table C. 5 Monthly, directly deposited fecal coliform loads in each reach of the Little River (Reaches 1,2,3,4,5,6,7,8,9,10,11,12,13,14,16,17,18,19,20,21,25,26, (cont.)

Source Type	Reach ID	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total Load (cfu/yr)
Human/Pet	21	87.8E11	79.3E11	87.8E11	84.9E11	87.8E11	84.9E11	87.8E11	87.8E11	84.9E11	87.8E11	84.9E11	87.8E11	10.3E13
Livestock	21	17.7E11	16.0E11	25.3E11	34.2E11	35.4E11	41.6E11	42.9E11	42.9E11	34.2E11	25.3E11	24.4E11	17.7E11	35.8E12
Wildlife	21	25.4E11	22.9E11	25.4E11	24.5E11	25.4E11	24.5E11	25.4E11	25.4E11	24.5E11	25.4E11	24.5E11	25.4E11	29.9E12
Human/Pet	25	17.1E11	15.4E11	17.1E11	16.5E11	17.1E11	16.5E11	17.1E11	17.1E11	16.5E11	17.1E11	16.5E11	17.1E11	20.1E12
Livestock	25	48.9E10	44.2E10	69.9E10	94.7E10	97.9E10	11.5E11	11.9E11	11.9E11	94.7E10	69.9E10	67.7E10	48.9E10	99.0E11
Wildlife	25	55.2E10	49.9E10	55.2E10	53.4E10	55.2E10	53.4E10	55.2E10	55.2E10	53.4E10	55.2E10	53.4E10	55.2E10	65.0E11
Human/Pet	26	24.5E11	22.1E11	24.5E11	23.7E11	24.5E11	23.7E11	24.5E11	24.5E11	23.7E11	24.5E11	23.7E11	24.5E11	28.9E12
Livestock	26	31.2E10	28.2E10	44.6E10	60.4E10	62.4E10	73.4E10	75.8E10	75.8E10	60.4E10	44.6E10	43.2E10	31.2E10	63.1E11
Wildlife	26	25.8E10	23.3E10	25.8E10	25.0E10	25.8E10	25.0E10	25.8E10	25.8E10	25.0E10	25.8E10	25.0E10	25.8E10	30.4E11
Human/Pet	27	96.8E10	87.4E10	96.8E10	93.7E10	96.8E10	93.7E10	96.8E10	96.8E10	93.7E10	96.8E10	93.7E10	96.8E10	11.4E12
Livestock	27	50.0E10	45.2E10	71.5E10	96.8E10	10.0E11	11.8E11	12.2E11	12.2E11	96.8E10	71.5E10	69.2E10	50.0E10	10.1E12
Wildlife	27	31.8E10	28.8E10	31.8E10	30.8E10	31.8E10	30.8E10	31.8E10	31.8E10	30.8E10	31.8E10	30.8E10	31.8E10	37.5E11

Table C. 6 Existing annual loads from land-based sources for the Little River (Sub-watersheds 1,2,3,4,5,6,7,8,9,10,11,12,13,14,16,17,18,19,20,21,25,26,27):

Source	Barren	Commercial	Crop	Developed	Forest	LAX	Pasture	Water	Wetland
Beaver	00E00	00E00	00E00	00E00	00E00	00E00	00E00	57.2E04	00E00
Beef Calves	00E00	00E00	00E00	00E00	00E00	32.6E13	88.3E14	14.0E13	00E00
Beef Stockers	00E00	00E00	00E00	00E00	00E00	64.8E13	17.2E15	27.2E13	00E00
Cat	00E00	00E00	00E00	24.1E07	00E00	00E00	00E00	00E00	00E00
Dairy Calves	00E00	00E00	17.5E13	00E00	00E00	00E00	97.0E11	00E00	00E00
Dairy Dry	00E00	00E00	21.1E13	00E00	00E00	00E00	11.7E12	00E00	00E00
Dairy Milkers	00E00	00E00	14.5E14	00E00	00E00	00E00	80.6E12	00E00	00E00
Deer	00E00	85.5E08	45.3E11	91.9E11	43.5E13	43.4E11	28.0E13	00E00	89.9E10
Dog	00E00	00E00	00E00	26.7E13	00E00	00E00	00E00	00E00	00E00
Duck	96.2E05	11.3E06	12.3E07	20.9E08	16.0E09	33.7E08	58.4E08	00E00	31.0E07
Goose	51.2E07	60.4E07	65.4E08	11.1E10	85.4E10	17.9E10	31.1E10	00E00	16.5E09
Hogs	00E00	00E00	00E00	00E00	00E00	00E00	00E00	00E00	00E00
Horses	00E00	00E00	00E00	00E00	00E00	00E00	86.5E13	00E00	00E00
Muskrat	14.6E11	17.2E11	18.6E12	31.7E13	24.3E14	51.1E13	88.6E13	00E00	47.0E12
People on Failing Septic	00E00	00E00	00E00	20.7E13	00E00	00E00	00E00	00E00	00E00
People on Straight Pipe	00E00	00E00	00E00	00E00	00E00	00E00	00E00	81.2E13	00E00
Raccoon	41.0E11	41.4E11	29.3E12	25.8E13	27.4E14	66.2E12	17.4E14	00E00	11.5E12
Sheep	00E00	00E00	00E00	00E00	00E00	00E00	30.6E12	00E00	00E00
Turkey	00E00	00E00	60.4E07	00E00	23.2E10	57.9E07	37.4E09	00E00	47.9E07

Table C. 7 Existing annual loads from direct-deposition sources for the Little River (Reaches 1,2,3,4,5,6,7,8,9,10,11,12,13,14,16,17,18,19,20,21,25,26,27):

Source	Annual Total Load (cfu/yr)
Beaver	57.2E04
Beef Calves	14.0E13
Beef Stockers	27.2E13
Dairy Calves	00E00
Dairy Dry	00E00
Dairy Milkers	00E00
Deer	36.8E10
Duck	10.8E08
Goose	37.9E09
Hogs	00E00
Horses	00E00
Muskrat	19.9E13
People on Straight Pipe	81.2E13
Raccoon	12.1E12
Sheep	00E00
Turkey	13.6E07